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MONTANA LARGE APERTURE SEISMIC ARRAY

FIRST QUARTERLY TECHNICAL REPORT, PROJECT VT 2708

CONTRACT F33657-72-C-0390

1 DECEMBER 1971 - 29 FEBRUARY 1972

15 March 1972

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13. ABSTRACT

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AFTAC Project No.: VELA T/2708

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ACRONYMS

AFSC	Air Force Systems Command
CTH	Central Terminal Housing
DIPEC	Defense Industrial Plant Equipment Center
IRSPS	Integrated Seismic Research Signal Processing System
LAMA	Large Aperture Microbarograph Array
LASA	Large Aperture Seismic Array
LASAPS	LASA Processing Subsystem
LDC	LASA Data Center
LMC	LASA Maintenance Center
LP	Long-Period
MDC	Maintenance Display Console
MOPS	Multiple On-line Processing System
PMEL	Precision Measurement and Equipment Laboratory
SAAC	Seismic Array Analysis Center
SDL	Seismic Data Laboratory
SEM	Subarray Electronics Module
SP	Short-Period
SPT	Special Test
TC	Telemetry Command
TFSO	Tonto Forest Seismological Observatory
VCO	Voltage Carrier Oscillator
VLR	Very Low Rate
VSC	VELA Seismological Center
WHV	Well Head Vault

SECTION I

INTRODUCTION

This report presents the accomplishments and administration of Contract Number F33657-72-C-0390. This contract between the Philco-Ford Corporation and AFSC Aeronautical Systems Division is for continued operation, research, and development of the Montana Large Aperture Seismic Array (LASA).

The LASA is part of the Vela Uniform Program which is sponsored by the Advanced Research Projects Agency of the Department of Defense. LASA is an experimental system consisting of many seismometers installed near Miles City, Montana, (Figure 1.1) and used for the development of appropriate methods for the detection and identification of seismic events. Initially, the detection, location, and identification of seismic data were performed at the LASA Data Center (LDC) location at Billings, Montana. However, subsequent to implementation of the Integrated Seismic Research Signal Processing System (IRSPS), the array data is now transmitted to the Seismic Array Analysis Center (SAAC) in Alexandria, Va., for processing and analysis.

Following a brief history and description of the LASA, a summary of the first quarters activities and accomplishments under Project V/T 2708 is presented in Section II. The details of the LASA operation is given in Section III. Array performance is discussed in Section IV. Section V describes the improvements and modifications made during this period. Maintenance activities are presented in Section VI. Assistance provided to other agencies is indicated in Section VII. Documentation provided is shown in Section VIII.

1.1 History

The LASA, installed in Eastern Montana during 1964 and 1965, is used for experiments in advanced seismological detection and discrimination. The initial installation, composed of 21 subarrays geometrically placed at a diameter of 200 kilometers with 525 short-period and 63 long-period seismometers, has evolved into the present array with the original 21 subarrays reduced to 347 short period seismometers and 51 long-period seismometers; 21 microbarographs and 8 weather stations have also been added.

Philco-Ford's participation in the Montana LASA began in 1964 by providing MIT Lincoln Laboratory with field engineering assistance. In June 1966, Philco-Ford assumed operational and maintenance responsibilities for MIT Lincoln Laboratory. On 1 May 1968, the project direction was transferred to the Electronics Systems Division, AFSC, with prime contracts to Philco-Ford through 30 November 1970.

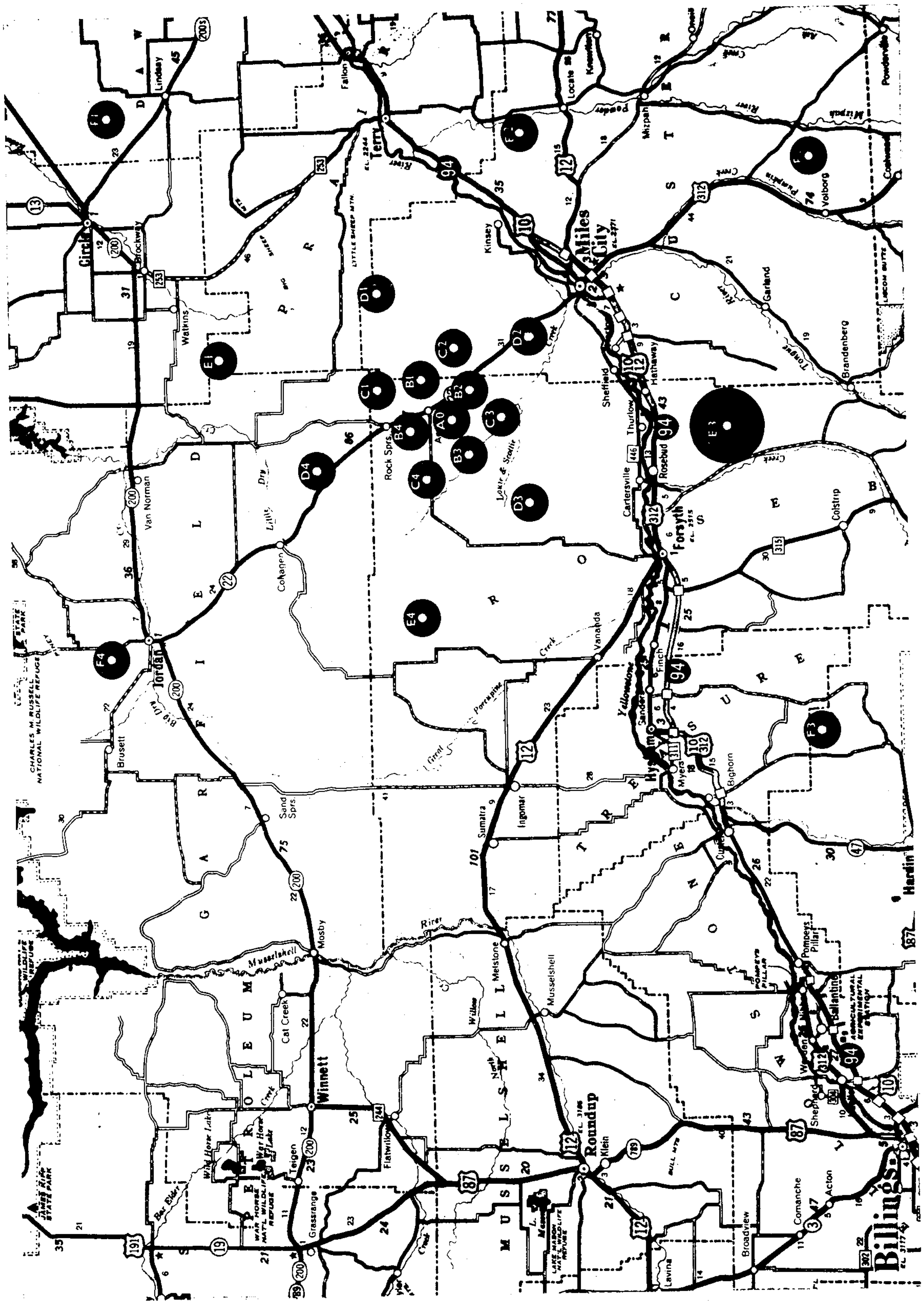


Figure 1.1 Montana LASA

Beginning 1 December 1970, technical direction of the Montana LASA was assigned to the Vela Seismological Center (VSC). Under Projects V/T 1708 and V/T 2708 Philco-Ford continues the work of previous Montana LASA projects. This work basically involves the continued operation and maintenance of the array and data center systems, logistics and administrative support, data provision, and hardware evaluation and installation.

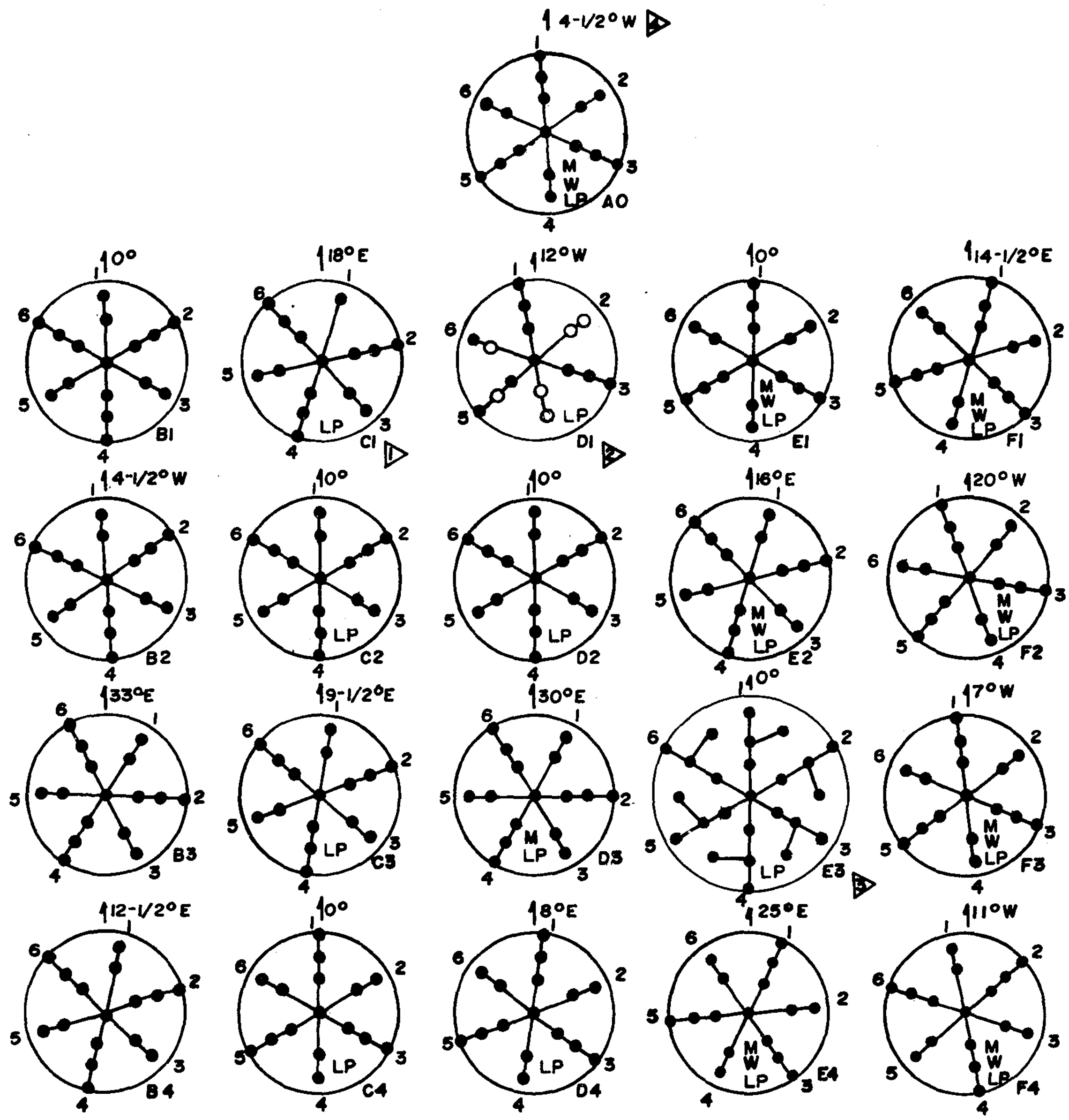
1.2 Description

The LASA with an overall diameter of 200 kilometers (124 miles) is composed of 21 subarrays arranged as shown in Figure 1.1. With the exception of subarray E3 which is 19 km in diameter, all subarrays are 7 km in diameter. Subarray E3 is configured with 25 short-period seismometers while all others now have 16. All subarrays originally were designed with 25 seismometers each, however, programmed sensor removal has now lowered this number to 16 except E3. The short-period seismometers are located along six radial cables which terminate in a central underground vault containing the Subarray Electronics Module (SEM). The subarrays also contain three-component long-period sensors, microbarograph sensors, and weather sensors. Figure 1.2 shows the present configuration of each subarray.

The LDC controls the array operation by sending a command signal to each SEM at a rate of twenty times each second to cause sampling of the subarray signals. This command signal is suitably delayed at the LDC prior to transmission so that data from all SEM's will arrive at the LDC within predetermined time intervals.

The SEM responds to LDC timing system control signals with signal sampling, conversion, and transmission of all data to the LDC. Flexibility exists within the array in that the SEM can accomodate as many as 30 signal inputs; currently, signals from short and long-period seismometers, weather sensing equipment, microbarograph sensors, and other measured parameters are telemetered. Signals from the 21 SEM's are transmitted to microwave junction points by open wire lines at a 19.2 kilobaud rate; from these points they are sent to the LDC by microwave radio facilities. At the LDC the data are recorded and reformatted for transmission over a 50 kilobaud channel to SAAC. The LDC also contains the array timing and maintenance monitoring equipment. By means of telemetry commands, signal sources at the subarray are controlled to provide equipment calibrations and verify equipment performance.

The different LASA seismographs operating parameters and tolerances are identified in Tables I and II. Figure 1.3 shows the five different seismograph responses available.



NOTES

1. Sensors removed from leg 1 because of access difficulties.
2. O Denotes near surface sensors.
3. Expanded array, 18 Km diameter.
4. All degrees shown are orientations with respect to true north.
5. LP Denotes long period seismometers exist at center of array.
6. M Denotes microbarograph sensors exist at center of array.
7. W Denotes weather sensors exist at center of array.

Figure 1.2 LASA Subarray Configurations

TABLE I

LASA SEISMOGRAPH OPERATING PARAMETERS AND TOLERANCES

CHANNEL IDENT.	OPERATING PARAMETERS AND TOLERANCES				
	T_s	λ_s	(MP_s)	S_{chan}	Full Scale Within
SPZ	1.0	0.7±0.1		20±3mV/nm@1.0s	609-823nm@1.0s
SPIZ	"	"		"	"
SPTZ	1.15	0.7		"	"
SPTN	1.06	"		"	"
SPTE	1.03	"		"	"
SPAZ	1.0	0.7±0.1		636±95mV/μm@1.0s	19.2-25.9μm@1.0s
LPZ	20.0±5%	0.77	0±1.5mm	350±50mV/μm@25s	35.0-46.7μm@25s
LPH	"	"	"	"	"
LPAZ	"	"	"	11±1.7mV/μm@25s	1102-1505μm@25s
LPAH	"	"	"	"	"
LPWZ	"	"	"	55±8.3mV/μm@25s	221-300μm@25s
LPWH	"	"	"	"	"

LEGEND: T_s = Seismometer Free Period (Sec); λ_s = Seismometer Damping

(MP_s) = Seismometer Mass Position from Center

S_{chan} = Channel Sensitivity

TABLE II

LASA SEISMOGRAPH CHANNEL IDENTIFICATION

CHANNEL	MANUFACTURER/MODEL	SEISMIC AMPLIFIER MFGR/MODEL	FILTER MFGR/MODEL/TYPE
SPZ	GeoSpace/HS-10-1A	Texas Inst./RA-5	4 pole $\frac{1}{2}$dB ripple Chebyshev low pass, f_c=5.0 hertz, @10 hertz, -30dB.
SPAZ	GeoSpace/HS-10-1A	Texas Inst./RA-5	
SPIZ	GeoSpace/HS-10-1B	Ithaco/6072-65	"
SPTZ	Teledyne/TD-201D	Texas Inst./RA-5	"
SPTN	Teledyne/TD-201D	Texas Inst./RA-5	"
SPTE	Teledyne/TD-201D	Texas Inst./RA-5	"
LPZ	Geotech/7505A	Texas Inst./Type II	Texas Inst./Type II/Response A. 24 dB/oct high-cut, centered at 65 sec.
LPH	Geotech/8700C	Texas Inst./Type II	
LPAZ	Geotech/7505A	Texas Inst./Type II	"
LPAH	Geotech/8700C	Texas Inst./Type II	"
LPWZ	Geotech/7507A	Texas Inst./Type II	Texas Inst./Type II/Response C. 12 dB/oct high-cut, centered at approx. 100 sec.
LPWH	Geotech/8700C	Texas Inst./Type II	

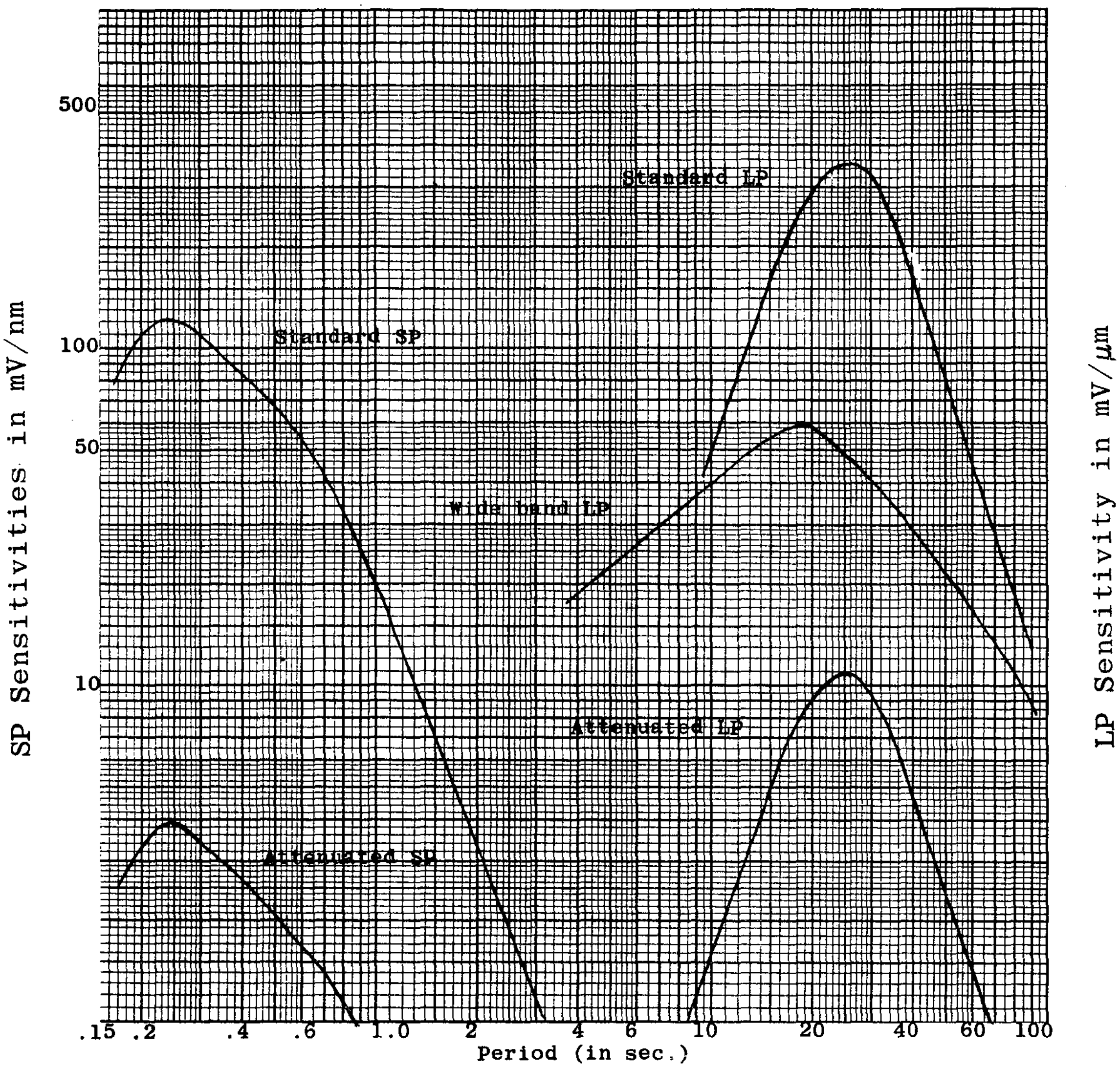


Figure 1.3 LASA Seismographs Response Curves

SECTION II

SUMMARY

The array operation, maintenance, and system improvement activities at the Montana LASA for the first quarterly period of the contract are described. The array operation support provided during the period to SAAC via the LDC computers which totaled 93.3% for on-line data transmission and 6.7% for back-up recording is detailed.

The results of the array monitoring and remote calibration performed are indicated. The array seismograph channel sensitivities averaged over the 91-day period were 20.2 mV/nm at 1s and 367.6 mv/μm at 25s for the short and long-period channels respectively. The sensitivity variation from channel to channel improved from the previous winter period for both seismograph systems. An investigation of a large sample of SP seismograph channels has been initiated and indicates an amplitude stability performance within ± 1 mV/nm at 1s.

A new PDP-7 computer program, TASP, has been prepared to measure remotely from the LDC the SP channel amplifier gains and seismometer output from 1 hertz sinusoidal calibration signals; this program is usable only on subarrays B1 and F3. The modification being prepared for installation in the Central Terminal Housing (CTH) to provide a short-period sensor channel gain adjustment is described. Removal of the microbarograph sensors from the B, C and D ring subarrays is also discussed.

Maintenance activity and equipment failure statistics are presented. The planned approach to be taken in the initiation of an equipment aging study has been included.

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SECTION III

OPERATION

3.1 General

Array operation is performed to provide data continuously from the array sensing and data acquisition systems to the LDC, to provide data on-line from the LDC to the SAAC, and to provide data recording in the event data transmission to SAAC is interrupted. Equipment maintenance (see Section VI) and the administrative function of logistics support the overall array operation.

3.2 Logistics

The logistics activity of the Montana array is divided into purchasing, property, and material. All operations were supported with a minimum of equipment down-time for parts. Fifty-four purchase orders were released to effect continuous array operation. The inventory presently contains 396 line items of property (DIPEC and SPT) and approximately 2500 material line items.

3.3 Data Center

The LASA Data Center (LDC) contains the equipment necessary to process the seismic array data either for transmission to SAAC or for recording locally. The activities in support of the LASAPS and other data center systems include: (1) IBM 360/44 computer operation on-line to SAAC, (2) PDP-7 computer operation to record array data in back-up of the 360 computer and to perform array monitoring, automatic calibrations, and off-line processing of array performance information, (3) maintenance display console operation for test and diagnosis of array equipment performance, (4) tape and film library operation for storage, handling, and shipment of array data recordings, (5) Develocorder operation for continuous recording of selected sensor channels for the Seismic Data Laboratory (SDL) and array quality control testing and analysis, and (6) telemetry link operation for continuous on-line data transmission of selected seismograph channels to MIT for data analysis.

3.3.1 SAAC/LDC Systems

Operation of the real-time data link between the SAAC and LDC so that a maximum amount of useful seismic data from the Montana array reaches SAAC for analysis is one of the main goals of our data center's operation. Monitoring of the SAAC/LDC operation during this quarterly period produced the operational statistics in Table III. Three operational modes which cause the outages shown are: (1) the SAAC computers are not available for LASAPS data acquisition, (2) the LDC Model 44 computer is not

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TABLE III

SAAC/LDC SYSTEM OPERATING TIMES
(Dec. 71 - Feb. 72)

	DEC.	JAN.	FEB.	TOTAL
SAAC & LDC 360 On-Line	698.2	697.1	643.5	2038.8
SAAC Off-Line, LDC 360 Running				
PDP-7 Recording	24.5	12.1	21.4	58.0
360 Idle	0.0	0.0	0.0	0.0
SAAC Up, LDC 360 Down, PDP-7 Recording				
Scheduled	2.1	2.8	3.8	8.7
Unscheduled	1.9	6.0	9.7	17.6
SAAC Up, Other Equipment Down, PDP-7 Recording				
Scheduled	0.0	0.0	0.0	0.0
Unscheduled	17.3	26.0	17.6	60.9
Totals (in hours)	744.0	744.0	696.0	2184.0

available for processing LASAPS data, and (3) the wideband communications channel between the LDC and SAAC is not in operation. These outage times are covered with digital recordings of the LASA data by the PDP-7 computer; however, no real-time data is available at SAAC. Periods in which LASAPS data was not used in the IRSPS operation at SAAC totaled 145.2 hours so that for 93.35% of this reporting period the SAAC/LDC systems operated together. The wideband data link between the two centers was inoperative 60.9 hours or 2.79% of the period.

3.3.2 IBM/360 Model 44 Computer

The IBM/360 computer, the LASAPS data processor, was fully operational at the LDC for 98.80% of this quarter. The complete computer utilization statistics are given in Table IV. On-line processing time equalled 96.01% of the period. Maintenance activities used 22.2 hours or 1.02% of the available time.

3.3.3 DEC PDP-7 Computer

The DEC PDP-7 computer was fully operational for data center processing 98.05% of this quarter in which on-line processing accounted for 87.20% and off-line 10.85%. The complete summary of computer utilization statistics is shown in Table V. The back-up operating mode of high-rate recording (Ref. 1) was required on 75 occasions covering an accumulated time period of 151.8 hours. During this operation 1144 magnetic tapes were recorded by the computer on 44 of the 91 days of this reporting period. Low-rate recordings totaling 1050 hours were also made. Both low-rate and high-rate recordings are retained at the LDC for at least 30 days of recycle time prior to reuse. Very-low-rate (VLR) recordings of microbarograph array data on the incremental recorder were made covering 1796.4 hours.

3.3.4 Analog System

Two Geotech Model 4000 Develocorders are operated at the LDC. One is used to support data analysis work at SDL and the other to support array maintenance by providing a means to display various sensor outputs during different intervals of time. The SDL Develocorder is operated 24 hours a day and each film record is scanned in the film viewer to determine the quality of the film record and provide a log of occurrences which affect the quality and usability of the film record.

3.3.5 Tape/Film Library

The data center's library is used to store the PDP-7 computer magnetic tape recordings, the 360 computer disc recordings, and the Develocorder film recordings prior to distribution and for reuse or reference. The library use statistics for this period are:

TABLE IV

SYSTEM/360 MODEL 44 COMPUTER UTILIZATION (DEC. 71 - FEB. 72)

OPERATION	ACCUMULATED TIME, HOURS			
	DEC.	JAN.	FEB.	TOTAL
On-line processing including:				
Fully operational with SAAC	698.2	697.1	643.5	2038.8
Running at LASA only	24.5	12.1	21.4	58.0
Down-time operating including:				
Scheduled maintenance	2.1	2.8	3.8	8.7
Corrective maintenance	1.9	4.5	7.1	13.5
Training	0.0	0.0	0.0	0.0
Shut down - 360 equipment	0.0	0.0	0.0	0.0
Shut down - other equipment	17.3	26.0	17.6	60.9
Program halt or loop	0.0	1.5	2.6	4.1
Idle time	0.0	0.0	0.0	0.0
Totals	744.0	744.0	696.0	2184.0

TABLE V

PDP-7 COMPUTER UTILIZATION (DEC. 71 - FEB. 72)

OPERATION	ACCUMULATED TIME, HOURS			
	DEC.	JAN.	FEB.	TOTAL
On-line program operation including:				
Monitor & Weather Processing only	7.0	24.1	15.2	46.3
VLR Recording only	199.8	217.5	239.5	656.8
High Rate Recording only	2.2	9.3	10.8	22.3
Low Rate Recording only	11.9	26.2	1.0	39.1
VLR & High Rate Recording	44.9	36.5	47.6	129.0
VLR & Low Rate Recording	374.6	329.6	306.2	1010.4
VLR, High & Low Rate Recording	0.1	0.1	0.0	0.2
High & Low Rate Recording	0.3	0.0	0.0	0.3
Off-line program operation including:				
Tape Duplication & Verification	6.0	6.7	6.7	19.4
Data Analysis	0.5	0.0	0.0	0.5
Utility Operation	12.9	14.7	8.0	35.6
Program Development	55.3	61.6	51.6	168.5
Diagnostic Programs & Testing	7.3	5.8	0.0	13.1
Training	0.0	0.0	0.0	0.0
System Initialization	0.0	0.0	0.0	0.0
Down-time operation including:				
Scheduled Maintenance	0.0	0.0	1.0	1.0
Corrective Maintenance	9.5	10.5	5.7	25.7
Shut down PDP-7 Inoperative	4.9	0.0	0.0	4.9
Shut down - Other Equipment	0.0	0.0	0.0	0.0
Program Halts	6.8	1.4	2.4	10.6
Idle	0.0	0.0	0.3	0.3
Totals	744.0	744.0	696.0	2184.0

1144 PDP-7 high-rate format tapes retained for recycling
3 PDP-7 high-rate format tapes distributed to SAAC
2 PDP-7 high-rate format tapes distributed to Lincoln Laboratory
80 PDP-7 very-low-rate format tapes distributed to SDL
787 PDP-7 low-rate format tapes retained for recycling
91 Develocorder films of SDL format distributed to SAAC

3.4 Array

Array operations functions performed include (1) monitoring of all array systems to detect equipment and data degradation, (2) testing of all array systems to measure equipment performance characteristics, (3) interfacing with telephone company personnel to determine communications equipment performance, and (4) processing of array maintenance and operation data to obtain statistics and information for efficient array management. These tasks are performed utilizing the PDP-7 computer, the maintenance display console, and the Develocorders. The overall system quality control efforts are applied through these activities.

3.4.1 Monitoring

Array monitoring refers to the sensing of performance of the operational equipment through the measurement of equipment characteristics on an essentially continuous basis. At the LDC continuous monitoring of the array systems is accomplished using the built-in data monitors, viz., (1) the MDC alarm monitor panel, (2) the PDP-7 monitor program and (3) the 360 computer's on-line system. The MDC alarm monitor panel provides instantly both a visual and audible indication at the occurrence of either a data link failure between the LDC and a subarray or an alarm signal of subarray power and vault failures transmitted on telemetry word 31. The PDP-7 monitor program outputs each telemetry word 31 data change from any subarray and also prints out the duration of subarray data interruptions. The 360 computer on-line system program periodically generates a variety of monitoring messages.

Operation and maintenance of the array equipment requires that the data be interrupted at various periods, during which time normal or reliable data may not be available to the LASA data user. The reasons established for data interruptions are: maintenance, either being performed or initiated; subarray equipment failure in which no maintenance has been initiated; telephone company(s) performing tests on the communication link not functioning; power outage at the subarray; or special data center testing. In the event any of these situations occur, a notation is made in the data interruption log relating to the data affected and the time period. For the case of short-period and long-period interruptions, SAAC is alerted via the System 360 typewriter. The total duration of data interruption reported for each subarray is broken down by month in Table VI.

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (DEC. 71 - FEB. 72)

SUB ARRAY	DATA	TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES) DEC.	JAN.	FEB.	TOTALS
AO	SP	0:0	0:0	0:07	0:07
	LP	0:0	0:0	0:07	0:07
	μbaro	0:0	0:0	0:07	0:07
	Meteor	0:0	0:0	0:07	0:07
	Telco	1:48	0:16	1:28	3:32
B1	SP	0:0	0:0	31:04	31:04
	μbaro	0:0	0:0	0:0	0:0
	Telco	1:48	0:0	0:0	1:48
B2	SP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Telco	1:48	0:0	0:0	1:48
B3	SP	0:0	0:0	0:37	0:37
	μbaro	0:0	0:0	0:37	0:37
	Telco	1:48	0:0	0:0	1:48
B4	SP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Telco	1:48	0:0	0:0	1:48
C1	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Telco	4:50	0:0	0:0	4:50
C2	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Telco	2:13	3:51	0:0	6:04
C3	SP	0:0	0:0	0:41	0:41
	LP	0:0	0:0	0:41	0:41
	μbaro	0:0	0:0	0:41	0:41
	Telco	1:48	0:0	0:0	1:48

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (CONTINUED)

SUB ARRAY	DATA	TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES)			
		DEC.	JAN.	FEB.	TOTALS
C4	SP	0:0	0:0	0:14	0:14
	LP	0:0	0:0	0:14	0:14
	μbaro	0:0	0:0	0:14	0:14
	Telco	41:51	0:0	0:0	41:51
D1	SP	0:0	0:0	0:26	0:26
	LP	0:0	0:0	0:26	0:26
	μbaro	0:0	0:0	0:26	0:26
	Telco	1:48	0:12	0:0	2:00
D2	SP	0:0	0:0	1:53	1:53
	LP	0:0	0:0	1:53	1:53
	μbaro	0:0	0:0	1:53	1:53
	Telco	0:0	0:0	0:0	0:0
D3	SP	0:0	0:0	0:49	0:49
	LP	0:0	0:0	0:49	0:49
	μbaro	0:0	0:0	0:49	0:49
	Telco	1:48	0:0	15:48	17:36
D4	SP	0:0	0:0	0:10	0:10
	LP	0:0	0:0	0:10	0:10
	μbaro	0:0	0:0	0:10	0:10
	Telco	1:48	2:51	0:0	4:39
E1	SP	0:0	0:0	0:30	0:30
	LP	0:0	0:0	0:30	0:30
	μbaro	0:0	0:0	0:30	0:30
	Meteor	0:0	0:0	0:30	0:30
	Telco	20:20	32:45	14:13	67:18
E2	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Meteor	0:0	0:0	0:0	0:0
	Telco	0:0	0:11	0:0	0:11

TABLE VI

SUBARRAY DATA INTERRUPTION OUTAGES (CONCLUDED)

SUB ARRAY	DATA	TOTAL TIME DURATION OF DATA INTERRUPTIONS (HOURS:MINUTES)			
		DEC.	JAN.	FEB.	TOTALS
E3	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	Telco	0:0	0:0	0:0	0:0
E4	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Meteor	0:0	0:0	0:0	0:0
	Telco	1:48	1:18	0:27	3:33
F1	SP	1:20	0:0	1:43	3:03
	LP	1:20	0:0	1:43	3:03
	μbaro	1:20	0:0	1:43	3:03
	Meteor	1:20	0:0	1:43	3:03
	Telco	9:54	0:0	:53	10:47
F2	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Meteor	0:0	0:0	0:0	0:0
	Telco	0:0	0:09	0:0	0:09
F3	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Meteor	0:0	0:0	0:0	0:0
	Telco	0:0	0:0	0:0	0:0
F4	SP	0:0	0:0	0:0	0:0
	LP	0:0	0:0	0:0	0:0
	μbaro	0:0	0:0	0:0	0:0
	Meteor	0:0	0:0	0:0	0:0
	Telco	15:44	24:27	6:10	46:21

3.4.2 Calibrations

Array calibrations refer to the performance sensing of the operational equipment through the periodic measurement of one or more equipment characteristics. Calibrations are performed daily for the short-period seismographs and weekly for the long-period seismographs from the LDC. The communications links between the LDC and each subarray provide the connection necessary for the set of telemetry command (TC) controls from which the condition of the various equipment may be determined remotely. Calibration of a complete seismograph channel is provided by TC-06 for the short-period system and TC-20 for the long-period system. Normal channel responses to these sinusoidal calibrations are shown in Table VII, where A (Volts) is the analog value, A (digital) is the digital value in decimal, and Y is the corresponding equivalent earth motion.

When the measured responses exceed the tolerances established for a particular channel, an equipment failure is reported. The report, the Defective Signal Channel Status Report, is distributed each week to authorized agencies. Table VIII indicates the incidence of defective channels detected during the three-month period for the four types of array channels.

The precise times in which array calibrations occur are readily available from the PDP-7 computer's MOPS on-line monitor program output. A report of these times for this quarterly period is shown in Tables IX and X for the SP and LP sensors respectively. For the short-period calibrations only one calibration time is shown in Table IX for each week; the daily times are available at the LDC. The equivalent earth motion of the calibration input signals to the seismometers are also shown in the two tables. Equivalent earth motion is determined from SEM channel 30 measurements during the calibration times. SEM channel 30 monitors the output of the sinusoidal oscillators which generate the signals applied to the seismometer.

Another calibration is the remote measurement adjustment of the long-period seismometer positioning performed by the PDP-7 computer. Using the appropriate telemetry commands, the PDP-7 computer controls on a weekly basis both the measurement and adjustment of each LP seismometer position. Program MASPOS maintains each seismometer mass to within ± 1.4 mm from its center position. Similarly, the seismometer natural frequencies are maintained to within 20 ± 1 sec/cycle by program FREECK. The number of these remote adjustments performed for each subarray is shown in Table VIII where the quantities in parenthesis indicate the out-of-tolerance measurements of seismometer mass position (169) and free-period (37) which are corrected remotely by telemetry.

TABLE VII

LASA SEISMOGRAPH CALIBRATION RESPONSE TOLERANCES

CHANNEL IDENT.	TC	Peak-to-Peak Sinusoidal Amplitudes								
		A_{nom} Volts	A_{max} Volts	A_{min} Volts	A_{nom} Digital	A_{max} Digital	A_{min} Digital	Y_{nom}	Y_{max}	Y_{min}
SPZ	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPAZ	06[1]	.25	.289	.214	293	407	236	395nm	455nm	336nm
SPIZ	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPTZ	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPTN	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
SPTE	06[1]	7.91	9.09	6.72	9257	10638	7864	395nm	455nm	336nm
LPZ	20[2]	6.98	7.98	5.99	8168	9339	7010	20.0μm	22.8μm	17.1μm
LPH	20[2]	6.98	7.98	5.99	8168	9339	7010	20.0μm	22.8μm	17.1μm
LPAZ	20[3]	2.77	3.19	2.34	3242	3733	2738	252μm	290μm	213μm
LPAH	20[3]	2.77	3.19	2.34	3242	3733	2738	252μm	290μm	213μm
LPWZ	20[2]	1.10	1.26	0.93	1287	1475	1088	20.0μm	22.9μm	16.9μm
LPWH	20[2]	1.10	1.26	0.93	1287	1475	1088	20.0μm	22.9μm	16.9μm

Note 1. Amplitude measurements corrected for response to 400nm, 1s calibration signal.
2. Amplitude measurements corrected for response to 20μm, 25s calibration signal.
3. Amplitude measurements corrected for response to 222μm, 25s calibration signal.

TABLE VIII

INCIDENCE OF DEFECTIVE SUBARRAY CHANNELS

December 1971 - February 1972

SUBARRAY	CHANNELS			
	SP	LP	μBARO	METEOR
AO	2	1 (15)	0	0
B1	0	-	0	-
B2	3	-	0	-
B3	5	-	1	-
B4	5	-	0	-
C1	2	2 (8)	1	-
C2	7	0 (12)	1	-
C3	0	0 (17)	1	-
C4	11	0 (8)	1	-
D1	3	0 (14)	2	-
D2	7	1 (19)	0	-
D3	2	0 (7)	0	-
D4	2	0 (13)	0	-
E1	2	0 (7)	0	0
E2	0	0 (13)	0	0
E3	3	0 (13)	-	-
E4	2	0 (16)	0	0
F1	8	1 (9)	0	0
F2	5	0 (21)	0	0
F3	2	0 (6)	0	0
F4	3	1 (8)	0	0
TOTALS	74	6 (206)	7	0

TABLE IX

SP ARRAY SINUSOIDAL CALIBRATIONS

SUBARRAY	Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes										SUBARRAY
	Day 341 7 Dec. 71		Day 347 13 Dec. 71		Day 354 20 Dec. 71		Day 361 27 Dec. 71		Day 003 3 Jan. 72		
	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	
AO	1619:11	438	1703:20	438	1702:12	437	2206:24	440	1603:03	441	AO
B1	1619:41	406	1703:50	406	1702:42	406	2206:54	406	1603:33	406	B1
B2	1620:11	414	1704:20	413	1703:12	412	2207:24	412	1604:03	414	B2
B3	1620:41	418	1704:50	423	1703:42	422	2207:54	422	1604:33	420	B3
B4	1621:11	406	1705:20	405	1704:12	405	2208:24	405	1605:03	405	B4
C1	1621:41	400	1705:50	400	1704:42	395	2208:54	400	1605:33	400	C1
C2	1622:11	407	1706:20	410	1705:12	410	2209:24	410	1606:03	408	C2
C3	1622:41	403	1706:50	405	1705:42	404	2209:54	404	1606:33	404	C3
C4	1623:11	395	1707:20	396	1706:12	394	2210:24	393	1607:03	393	C4
D1	1623:41	407	1707:50	406	1706:42	407	2210:54	408	1607:33	406	D1
D2	1624:11	392	1708:20	392	1707:12	391	2211:24	390	1608:03	390	D2
D3	1624:41	392	1708:50	391	1707:42	392	2211:54	391	1608:33	390	D3
D4	1625:11	410	1709:20	410	1708:12	405	2212:24	402	1609:03	410	D4
E1	1625:41	412	1709:50	414	1708:42	410	2212:54	414	1609:33	413	E1
E2	1626:11	423	1710:20	423	1709:12	414	2213:24	423	1610:03	423	E2
E3	1626:41	404	1710:50	405	1709:42	405	2213:54	404	1610:33	404	E3
E4	1627:11	416	1711:20	416	1710:12	416	2214:24	417	1611:03	418	E4
F1	1627:41	406	1711:50	404	1710:42	404	2214:54	404	1611:33	404	F1
F2	1628:11	408	1712:20	408	1711:12	410	2215:24	408	1612:03	408	F2
F3	1628:41	415	1712:50	417	1711:42	416	2215:54	418	1612:33	417	F3
F4	1629:11	416	1713:20	416	1712:12	416	2216:24	415	1613:03	415	F4

TABLE IX

SP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes										SUBARRAY
	Day 010 10 Jan. 72		Day 017 17 Jan. 72		Day 024 24 Jan. 72		Day 031 31 Jan. 72		Day 038 7 Feb. 72		
	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	
AO	1632:49	440	1621:01	441	2045:35	442	1543:59	436	1532:26	435	AO
B1	1633:19	406	1621:31	405	2046:05	405	1544:29	405	1532:56	405	B1
B2	1633:49	412	1622:01	413	2046:35	411	1544:59	413	1533:26	410	B2
B3	1634:19	421	1622:31	422	2047:05	426	1545:29	423	1533:56	426	B3
B4	1634:49	404	1623:01	403	2047:35	402	1545:59	402	1534:26	400	B4
C1	1635:19	400	1623:31	400	2048:05	400	1546:29	396	1534:56	400	C1
C2	1635:49	410	1624:01	412	2048:35	413	1546:59	411	1535:26	415	C2
C3	1636:19	404	1624:31	402	2049:05	404	1547:29	404	1535:56	404	C3
C4	1636:49	394	1625:01	394	2049:35	393	1547:59	395	1536:26	395	C4
D1	1637:19	405	1625:31	408	2050:05	407	1548:29	405	1536:56	408	D1
D2	1637:49	384	1626:01	390	2050:35	390	1548:59	385	1537:26	385	D2
D3	1638:19	391	1626:31	391	2051:05	390	1549:29	387	1537:56	380	D3
D4	1638:49	412	1627:01	412	2051:35	412	1549:59	412	1538:26	412	D4
E1	1639:19	407	1627:31	412	2052:05	414	1550:29	414	1538:56	414	E1
E2	1639:49	423	1628:01	423	2052:35	423	1550:59	423	1539:26	414	E2
E3	1640:19	404	1628:31	404	2053:05	403	1551:29	404	1539:56	404	E3
E4	1640:49	416	1629:01	415	2053:35	418	1551:59	413	1540:26	417	E4
F1	1641:19	405	1629:31	406	2054:05	406	1552:29	406	1540:56	407	F1
F2	1641:49	405	1630:01	408	2054:35	408	1552:59	408	1541:26	401	F2
F3	1642:19	417	1630:31	410	2055:05	420	1553:29	420	1541:56	417	F3
F4	1642:49	415	1631:01	415	2055:35	415	1553:59	415	1542:26	415	F4

TABLE IX

SP ARRAY SINUSOIDAL CALIBRATIONS (CONCLUDED)

SUBARRAY	Short-Period Array Sinusoidal Calibration Signal Start Times and Amplitudes						SUBARRAY
	Day 045 14 Feb. 72		Day 052 21 Feb. 72		Day 059 28 Feb. 72		
	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	Start Time (GMT)	P-P Ampl. nm	
AO	1800:53	441	1542:11	435	1507:55	443	AO
B1	1801:23	405	1542:41	405	1508:25	397	B1
B2	1801:53	411	1543:11	411	1508:55	408	B2
B3	1802:23	424	1543:41	421	1509:25	422	B3
B4	1802:53	403	1544:11	402	1509:55	395	B4
C1	1803:23	400	1544:41	402	1510:25	400	C1
C2	1803:53	415	1545:11	414	1510:55	414	C2
C3	1804:23	402	1545:41	404	1511:25	404	C3
C4	1804:53	395	1546:11	395	1511:55	394	C4
D1	1805:23	406	1546:41	406	1512:25	408	D1
D2	1805:53	386	1547:11	385	1512:55	385	D2
D3	1806:23	388	1547:41	388	1513:25	388	D3
D4	1806:53	412	1548:11	405	1513:55	414	D4
E1	1807:23	414	1548:41	407	1514:25	412	E1
E2	1807:53	423	1549:11	422	1514:55	418	E2
E3	1808:23	398	1549:41	403	1515:25	403	E3
E4	1808:53	418	1550:11	416	1515:55	418	E4
F1	1809:23	398	1550:41	407	1516:25	407	F1
F2	1809:53	404	1551:11	408	1516:55	408	F2
F3	1810:23	416	1551:41	418	1517:25	418	F3
F4	1810:53	415	1552:11	415	1517:55	414	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude									SUBARRAY
	Day 342: 8 Dec. 71			Day 347: 13 Dec. 71			Day 354: 20 Dec. 71			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	2105:40	2108:40	20.4	2126:48	2129:48	20.1	1716:49	1719:49	20.1	AO
C1	"	"	20.1	"	"	19.9	"	"	20.1	C1
C2	2113:40	2116:40	266	2134:48	2137:48	263	1724:49	1727:49	262	C2
C3	"	"	20.2	"	"	20.2	"	"	20.2	C3
C4	2121:40	2124:40	21.1	2142:48	2145:48	20.6	1732:49	1735:49	21.3	C4
D1	"	"	20.9	"	"	20.3	"	"	20.5	D1
D2	2129:40	2132:40	20.7	2150:48	2153:48	20.7	1740:49	1743:49	20.7	D2
D3	"	"	20.5	"	"	20.5	"	"	20.4	D3
D4	2137:40	2140:40	21.0	2158:48	2201:49	21.0	1748:49	1751:49	21.0	D4
E1	"	"	20.0	"	"	19.9	"	"	19.9	E1
E2	2145:40	2148:40	19.9	2206:49	2209:49	20.0	1756:49	1759:49	20.1	E2
E3	"	"	19.9	"	"	19.9	"	"	19.9	E3
E4	2153:40	2156:41	20.2	2214:49	2217:49	19.6	1804:50	1807:50	19.6	E4
F1	"	"	20.5	"	"	20.5	"	"	20.5	F1
F2	2201:41	2204:41	21.1	2222:49	2225:49	21.0	1812:50	1815:50	21.1	F2
F3	"	"	20.1	"	"	20.0	"	"	20.1	F3
F4	2209:41	2212:41	20.1	2230:49	2233:49	20.1	1820:50	1823:50	19.5	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude									SUBARRAY
	Day 361: 27 Dec. 71			Day 003: 3 Jan. 72			Day 010: 10 Jan. 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	2049:27	2052:27	20.4	1711:57	1714:57	20.4	1651:16	1654:16	20.1	AO
C1	"	"	20.2	"	"	20.2	"	"	19.9	C1
C2	2057:27	2100:27	259	1719:57	1722:57	261	1659:16	1702:16	269	C2
C3	"	"	20.2	"	"	20.2	"	"	20.2	C3
C4	2105:27	2108:27	20.9	1727:57	1730:57	20.4	1707:16	1710:17	20.5	C4
D1	"	"	20.3	"	"	20.3	"	"	20.3	D1
D2	2113:27	2116:27	20.7	1735:57	1738:57	20.7	1715:17	1718:17	20.6	D2
D3	"	"	20.4	"	"	20.5	"	"	21.3	D3
D4	2121:27	2124:27	21.0	1743:57	1746:57	21.0	1723:17	1726:17	21.0	D4
E1	"	"	19.9	"	"	19.9	"	"	19.9	E1
E2	2129:28	2132:28	19.9	1751:57	1754:57	19.9	1731:17	1734:17	20.3	E2
E3	"	"	20.1	"	"	19.9	"	"	20.4	E3
E4	2137:28	2140:28	19.6	1759:58	1802:58	20.2	1739:17	1742:17	20.4	E4
F1	"	"	20.5	"	"	20.5	"	"	20.5	F1
F2	2145:28	2148:28	21.0	1807:58	1810:58	21.0	1815:38	1818:38	21.1	F2
F3	"	"	19.8	"	"	19.8	1824:46	1827:46	20.3	F3
F4	2153:28	2156:28	19.4	1815:58	1818:58	19.9	1755:17	1758:17	19.5	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude									SUBARRAY
	Day 017: 17 Jan. 72			Day 024: 24 Jan. 72			Day 031: 31 Jan. 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	1645:00	1648:00	20.2	1807:45	1810:45	20.1	1600:48	1603:49	20.2	AO
C1	"	"	20.2	"	"	20.4	"	"	20.1	C1
C2	1653:00	1656:00	268	1815:45	1818:45	260	1608:49	1611:49	266	C2
C3	"	"	20.2	"	"	20.2	"	"	20.2	C3
C4	1701:00	1704:00	20.5	1823:45	1826:45	20.5	1616:49	1619:49	20.7	C4
D1	"	"	20.8	"	"	21.0	"	"	20.3	D1
D2	1709:01	1712:01	20.6	1831:45	1834:45	20.7	1624:49	1627:49	20.7	D2
D3	"	"	20.5	"	"	21.0	"	"	20.6	D3
D4	1717:01	1720:01	21.0	1839:45	1842:45	21.2	1632:49	1635:49	20.9	D4
E1	"	"	19.9	"	"	19.9	"	"	19.9	E1
E2	1725:01	1728:01	20.0	1847:45	1850:45	20.1	1640:49	1643:49	20.6	E2
E3	"	"	20.6	"	"	20.6	"	"	19.9	E3
E4	1733:01	1736:01	19.8	1855:46	1858:46	20.3	1648:49	1651:49	20.3	E4
F1	"	"	20.4	"	"	20.5	"	"	20.5	F1
F2	1741:01	1744:01	21.1	1903:46	1906:46	21.0	1656:50	1659:50	21.0	F2
F3	"	"	20.5	"	"	20.4	"	"	19.8	F3
F4	1749:01	1752:01	20.0	1911:46	1914:46	19.5	1704:50	1707:50	20.1	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONTINUED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude						SUBARRAY
	Day 038: 7 Feb. 72			Day 045: 14 Feb. 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	1725:00	1728:00	20.1	2103:22	2106:22	20.3	AO
C1	"	"	20.4	"	"	20.5	C1
C2	1733:00	1736:00	267	2111:22	2114:22	264	C2
C3	"	"	20.1	"	"	20.2	C3
C4	1741:00	1744:01	21.1	2119:22	2122:23	21.3	C4
D1	"	"	20.4	"	"	21.1	D1
D2	1749:01	1752:01	20.5	2127:23	2130:23	20.6	D2
D3	"	"	20.4	"	"	20.5	D3
D4	1757:01	1800:01	21.0	2135:23	2138:23	21.0	D4
E1	"	"	19.9	"	"	19.9	E1
E2	1805:01	1808:01	20.3	2143:23	2146:23	20.7	E2
E3	"	"	20.4	"	"	20.2	E3
E4	1813:01	1816:01	20.1	2151:23	2154:23	20.1	E4
F1	"	"	20.5	"	"	20.5	F1
F2	1821:01	1824:01	21.0	2159:23	2202:23	21.1	F2
F3	"	"	20.5	"	"	19.8	F3
F4	1829:01	1832:01	19.7	2207:23	2210:23	20.1	F4

TABLE X

LP ARRAY SINUSOIDAL CALIBRATIONS (CONCLUDED)

SUBARRAY	Long-Period Array Sinusoidal Calibration Signal Times and Input Amplitude						SUBARRAY
	Day 052: 21 Feb. 72			Day 059: 28 Feb. 72			
	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	Start Time (GMT)	Stop Time (GMT)	Input Ampl. μm P-P	
AO	1620:16	1623:16	20.2	1627:49	1630:49	20.5	AO
C1	"	"	20.4	"	"	20.4	C1
C2	1628:16	1631:16	265	1635:49	1638:49	261	C2
C3	"	"	20.2	"	"	20.2	C3
C4	1636:16	1639:16	20.5	1643:50	1646:50	20.9	C4
D1	"	"	20.3	"	"	20.3	D1
D2	1644:16	1647:16	20.6	1651:50	1654:50	20.6	D2
D3	"	"	21.1	"	"	20.5	D3
D4	1652:16	1655:16	21.1	1659:50	1702:50	20.9	D4
E1	"	"	20.0	"	"	19.9	E1
E2	1700:16	1703:16	20.8	1707:50	1710:50	20.7	E2
E3	"	"	20.4	"	"	20.0	E3
E4	1708:17	1711:17	20.1	1715:50	1718:50	19.6	E4
F1	"	"	20.5	"	"	20.5	F1
F2	1716:17	1719:17	21.1	1723:50	1726:50	21.1	F2
F3	"	"	20.5	"	"	19.8	F3
F4	1724:17	1727:17	19.8	1731:50	1734:51	20.0	F4

3.4.3 Communications

The interface between array and data center provided by the communications systems plays an important part in the success of the array operation. Determination of data interruptions due to telephone circuit outages is one responsibility of the LDC operations activity. All outages reported by data center personnel are assigned a ticket number to aid in accounting for and identifying of the data interruption. Weekly meetings are held with the telephone company, viz., Mountain Bell and Mid Rivers, personnel to review and describe all outages.

During this winter period between December 71 and February 72 the outages which exceeded a two-hour duration are listed in Table XI. The reason attributed to each outage is indicated. Frost on the lines increases the resistance and attenuates the data signal to such low levels that broken data occurs. Static buildup on the lines occurs during blowing snow so that broken data also results when storm conditions are in the array. Damage to bridle wires caused by the drive rings pulling out from the pole resulted in five outage reports. The bridle wire is the wire leading from the end telephone pole down to the underground CTH.

TABLE XI

EXTENDED ARRAY DATA INTERRUPTIONS DUE TO COMMUNICATIONS OUTAGES

DATE	DURATION	SITE	REASON FOR OUTAGE
12/15/71	5:27	F4	Frost on line near subarray
12/16/71	5:46	F4	Noise on line - storm in subarray area
12/16/71	5:46	F1	Noise on line - storm in subarray area
12/16/71	3:03	C1	Noise on line - storm in subarray area
12/25/71	12:26	C4	Damaged bridle wire
12/25/71	9:34	E1	Storm in subarray area
12/26/71	10:38	C4	Damaged bridle wire
12/26/71	8:51	E1	Storm in subarray area
12/27/71	2:43	F4	Storm in subarray area
12/27/71	2:43	F1	Storm in subarray area
12/27/71	13:53	C4	Damaged bridle wire & Telco corrective maintenance
01/04/72	8:26	F4	Frost on line near subarray
01/12/72	4:57	E1	Damaged bridle wire
01/18/72	12:53	E1	Damaged bridle wire & Telco corrective maintenance
01/23/72	14:28	F4	Frost on line near subarray
01/23/72	3:41	E1	Frost on line near subarray
01/23/72	2:51	D4	Frost on line near subarray
01/23/72	3:31	C2	Frost on line near subarray
02/10/72	6:10	F4	Frost on line near subarray
02/12/72	14:22	D3	Bad oscillator at Mountain Bell Toll Test
02/17/72	8:43	E1	Wire slap near subarray
02/23/72	5:03	E1	Wire slap near subarray

SECTION IV

ARRAY PERFORMANCE

4.1 Systems

The overall performance measure applied to each of the array's sensor systems is the array data availability. The percentage of time the array systems are on-line providing quality data determine the value of this measure. Data availabilities are calculated by combining the total subarray data interruption times shown in Table VI with the total sensor outage times reported on the Defective Signal Channel Status reports. The data availabilities compared with those of previous periods are as follows:

	1st Quarter	Previous 1st Quarter	Previous Contract
SP	93.3	95.5	96.7
LP	93.2	98.4	98.6
μbaro	92.5	97.9	97.4
Met	100.0	99.5	99.2

Telephone circuit and power outages which affect all subarray systems are not included in the percentages. During this quarterly period the listed data availabilities were further reduced by 0.5% by the telco outages.

4.1.1 SP Seismograph

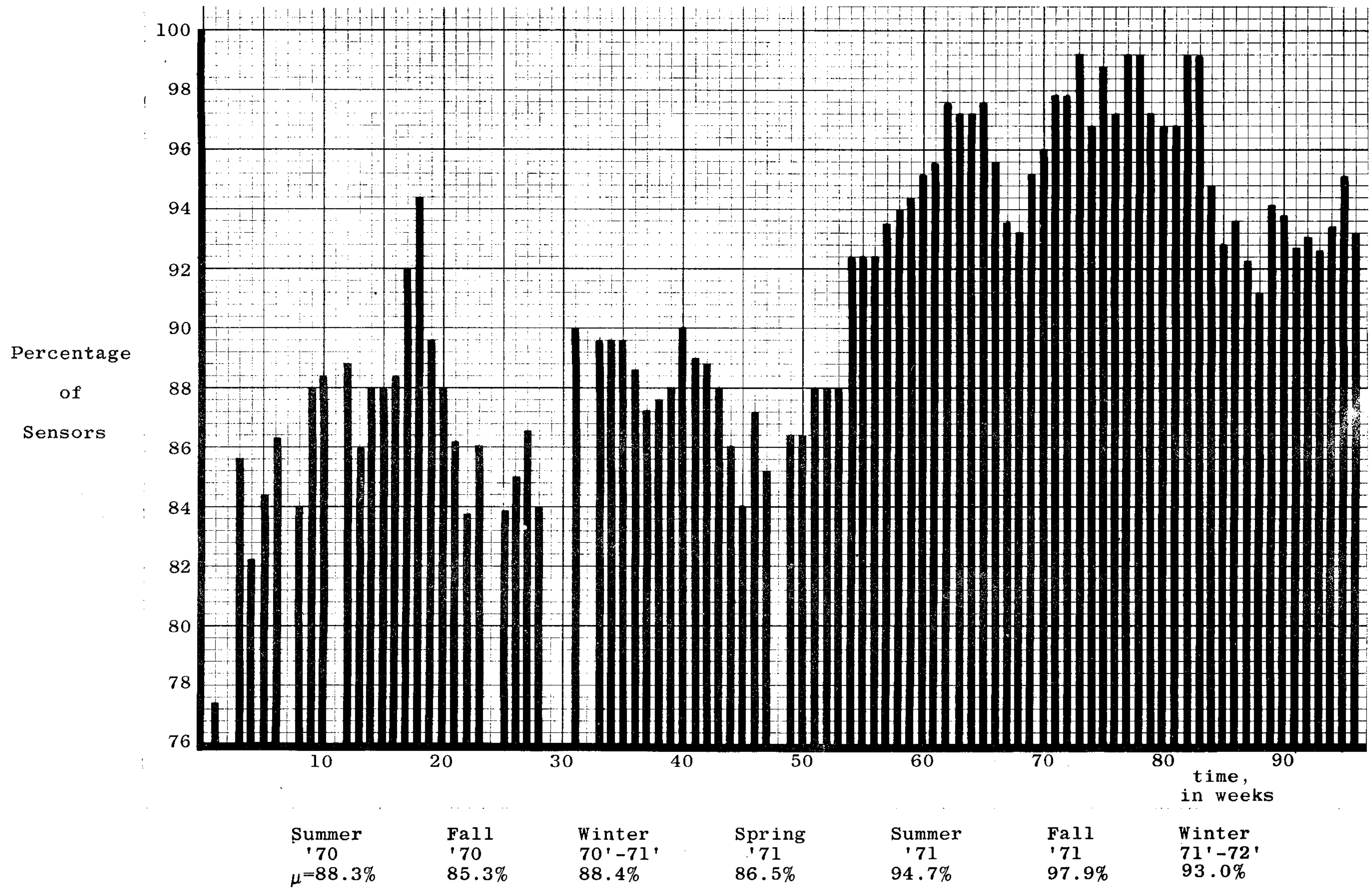
Following the procedure of the previous contract the performance monitoring of the 345 short-period seismograph channels continued throughout this quarterly period. An average channel sensitivity of 20.20 mV/nm at 1s with a standard deviation of 1.58 is reported for the period. A summary of test results obtained each week is shown in Table XII where the statistics are compared with those of the previous contract and those of the previous December-February period. Comparison shows improvement over the similar period last year. This is attributed to the SP array maintenance program (Ref. 2).

The distribution showing the SP sensors within the ± 15% sensitivity tolerance has been continued to indicate further the cyclic variation that occurs with the seasonal temperature changes. Figure 4.1 shows the percentage of SP sensors within the tolerance for the 23 month period from 30 March 1970 through 29 February 1972. The effect of this recent winter season on the amplitude stability of the channels can be seen in the distribution.

TABLE XII

SP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

DATE	NO. SENSORS	SENS. MEAN mV/nm	SENS. σ mV/nm	SENS. MAX. mV/nm	SENS. MIN. mV/nm	SENS. DEV. mV/nm
12/7	342	20.54	1.52	23.7	15.0	8.7
12/14	343	20.24	1.58	23.5	13.2	10.3
12/21	343	20.34	1.52	23.4	16.0	7.4
12/28	345	20.18	1.56	23.4	14.7	8.7
1/3	344	20.14	1.62	23.3	14.9	8.4
1/10	342	20.23	1.55	23.5	15.3	8.2
1/17	345	20.30	1.51	23.5	15.1	8.4
1/24	342	20.06	1.64	23.6	13.8	9.8
1/31	343	19.94	1.68	23.0	13.4	9.6
2/7	343	19.97	1.71	23.3	13.0	10.3
2/14	343	20.19	1.56	23.8	13.7	10.1
2/21	344	20.30	1.53	23.3	14.5	8.8
2/28	343	20.18	1.56	24.0	15.2	8.8
AVERAGE	343.23	20.20	1.58	23.48	14.45	9.04
PREVIOUS 1ST QTR. AVERAGE	344.7	20.3	2.11	30.3	10.8	19.4
PREVIOUS CONTRACT AVERAGE	343.9	20.36	1.694	26.5	12.7	13.8



4.1 Percentage Distribution of SP Sensors in ± 15% Sensitivity Tolerance

For the purpose of determining individual channel stability 86 SP channels were picked from the array to receive special study. Six of these channels were picked at random from subarray E3 and four were picked at random from each of the other 20 subarrays. The sensitivities of each of these 86 channels since 1 November 1971 have been obtained from the daily printout of program TESP. At the end of each month a standard deviation of the sensitivity was calculated for each channel picked. Table XIII is a summary of this data.

This table reflects the effect of adverse weather conditions on the array sensitivity. During the month of January when extreme cold fronts moved across Montana, the mean and standard deviation was highest while the number of channels having a standard deviation less than 0.3333 mV/nm was lowest.

For the large number of random samples the distribution of a non-normal distribution can be very nearly approximated by a normal distribution with the same mean and standard deviation. Various numerical studies have indicated that in typical practical applications a sample size of 25 is sufficient for the normal approximation to be useful (Ref. 3).

Taking the sensitivity of a channel daily over a month will give a sample size of at least 28. This would imply that if the sensitivity of a channel is not normally distributed that it can be be usefully approximated by a normal distribution of the same mean and standard deviation.

Assuming the distribution of the sensitivity of an individual channel to be normal or at least approximated by a normal distribution, the data in Table XIII shows that in the large majority of cases the sensitivity reading of a channel will be within 1 mV/nm of the mean sensitivity. For example, in the month of November 1971, 95.3% of the 86 channels have a standard deviation less than 0.3333 mV/nm. With the assumption that the sensitivity of an individual channel is normally distributed 99.8% of the readings will be within 3 standard deviations of the mean, i.e., in 95.3% of the cases for November, 99.8% of the readings will be within 1 mV/nm of the mean.

4.1.2 LP Seismograph

The performance monitoring of the 45 standard LASA LP long-period sensors continued during the quarterly period following the procedures of the previous contract. A channel sensitivity average of 367.57 mV/μm at 25s and a standard deviation of 17.78 is reported from these seismographs for the three-month period. The weekly test results obtained are shown in Table XIV where this quarter's statistics are summarized and compared with those of the previous contract and those of the previous December - February period.

TABLE XIII

A DISTRIBUTION OF THE STANDARD DEVIATIONS OF 86 LASA SP CHANNELS

	MEAN S In mV/nm	MAXIMUM S In mV/nm	MINIMUM S In mV/nm	% <.3333 mV/nm
Nov. 71	0.1831	1.072	0.0570	95.3
Dec. 71	0.2236	1.945	0.0277	86.0
Jan. 72	0.2902	1.306	0.0807	73.3
Feb. 72	0.2559	1.690	0.0630	80.2

TABLE XIV

LP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

DATE	NO. SENSORS	SENS. MEAN mV/μm	SENS. σ mV/μm	SENS. MAX. mV/μm	SENS. MIN. mV/μm	SENS. DEV. mV/μm
12/8	45	364.7	19.3	425	337	88
12/14	45	365.2	15.1	416	338	78
12/21	45	366.5	18.2	423	337	86
12/28	45	366.0	18.7	416	319	97
1/3	45	370.5	20.2	421	326	95
1/10	45	369.3	17.8	416	340	76
1/17	45	368.8	17.9	427	343	84
1/24	45	369.4	18.4	418	344	74
1/3	45	367.3	18.4	415	306	109
2/7	45	369.9	17.5	418	337	81
2/14	45	366.1	18.3	414	299	115
2/21	44	367.1	15.8	415	337	78
2/28	44	367.6	15.5	416	337	79
AVERAGE	44.85	367.57	17.78	418.46	330.77	87.69
PREVIOUS 1ST QTR. AVERAGE	45.0	368.5	22.0	420	306	114
PREVIOUS CONTRACT AVERAGE	44.6	356.1	18.8	403	312	90

Plotted in Figure 4.2 is the percentage distribution of the LP sensors within the 350 ± 50 mV/μm sensitivity tolerance throughout the 15 month period starting 8 December 1970 through 28 February 1972.

4.1.3 Microbarograph Array

During this quarter the number of sensors in the microbarograph array was reduced from 22 to 9. The ESYS microbarographs installed at the thirteen subarrays in the B, C, and D-rings and AO are being removed. The LAMA is now comprised of only LTV-6 microbarograph sensors installed at the locations shown in Figure 4.3. The frequency responses now covered by the array are shown in Figure 4.4.

4.2 Equipment

4.2.1 SP Calibration Oscillator

The performance characteristics of the one-hertz oscillator used to produce the SP array calibration signals during remote tests from the LDC are shown in Table XV. This table was prepared to identify the operational characteristics of the signals used during array calibrations. The table is divided into two parts, first, to indicate what characteristics can be expected from a calibration signal at any subarray, and second, to show the improvement in signal characteristics if an individual subarray is selected. The performance figures reported are for the test period indicated, e.g., the expected amplitude stability of any calibration signal in the array is within ±5% over a 15-week period.

During January 6 - February 6, the oscillators' output frequencies were measured daily with an Hewlett Packard 5245L electronic counter. Telemetry command TC-14 connects the oscillator's output directly to channel 30 and provides a signal for measurement that does not affect the subarray's data channels. The results of this test, shown in Table XVI, reflect the frequency characteristics of the oscillator with a degree of precision not provided by the daily SP sensor test program, TESP.

The test results indicate a high degree of stability of the calibration oscillator. The maximum standard deviation among the 21 oscillators over the 32-day time span is 0.37 millisecond at subarray C4. The greatest difference in period, 1.985 ms, also occurred at subarray C4. The oscillator at subarray D1 shows the greatest degree of stability with a standard deviation of 0.11 millisecond and difference between extremes of 0.512 millisecond.

The oscillator's frequency stability was measured to determine the effect of oscillator drift on the daily SP channel sensitivity calculations made by program TESP. These calculations assume a calibration oscillator period of 1.0 second. Any variation in the oscillator period is not reflected in the reported

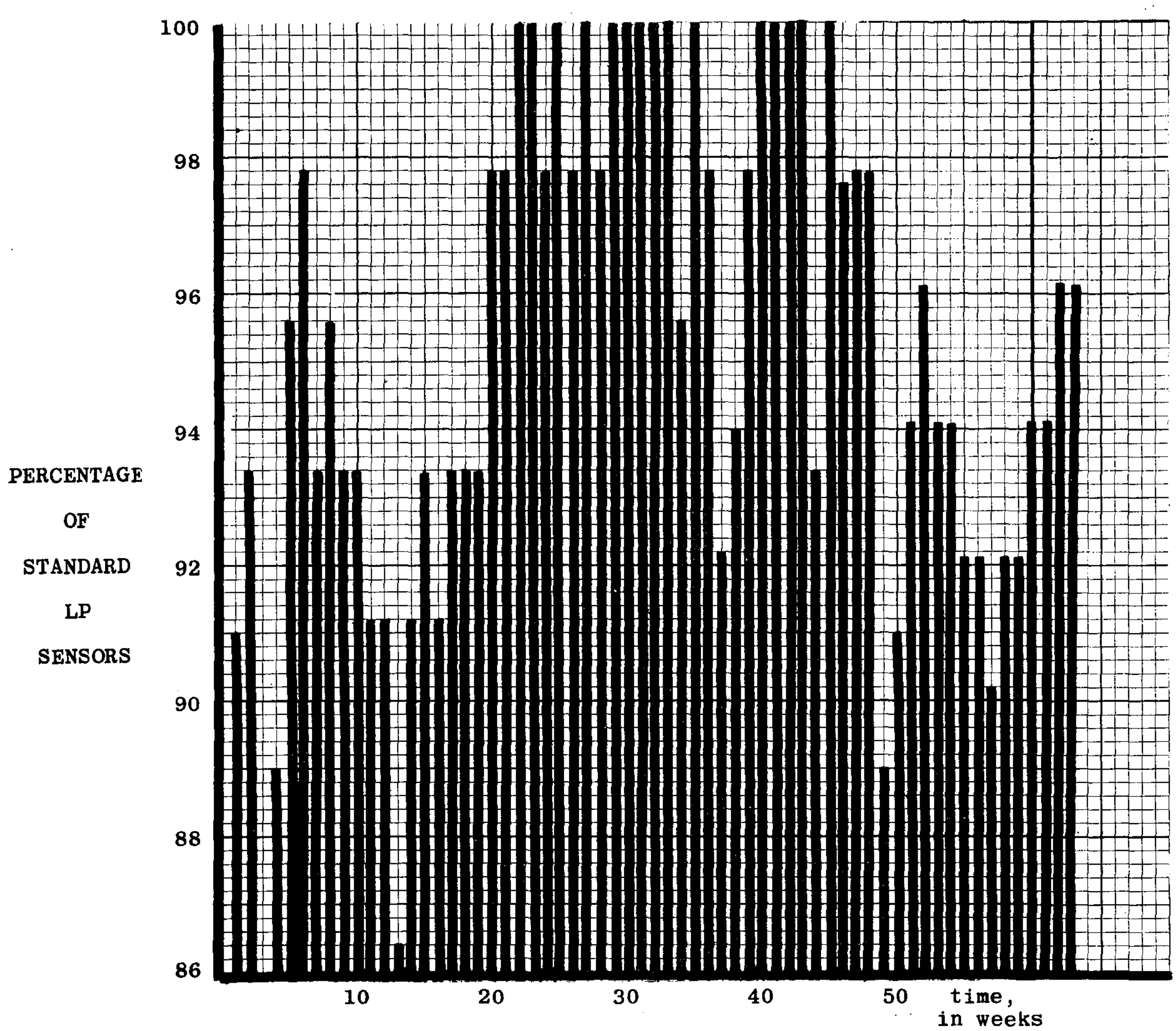


Figure 4.2 Percentage Distribution of LP Sensors within ± 50 mV/μm Sensitivity Tolerance from 8 December 1970 through 28 February 1972

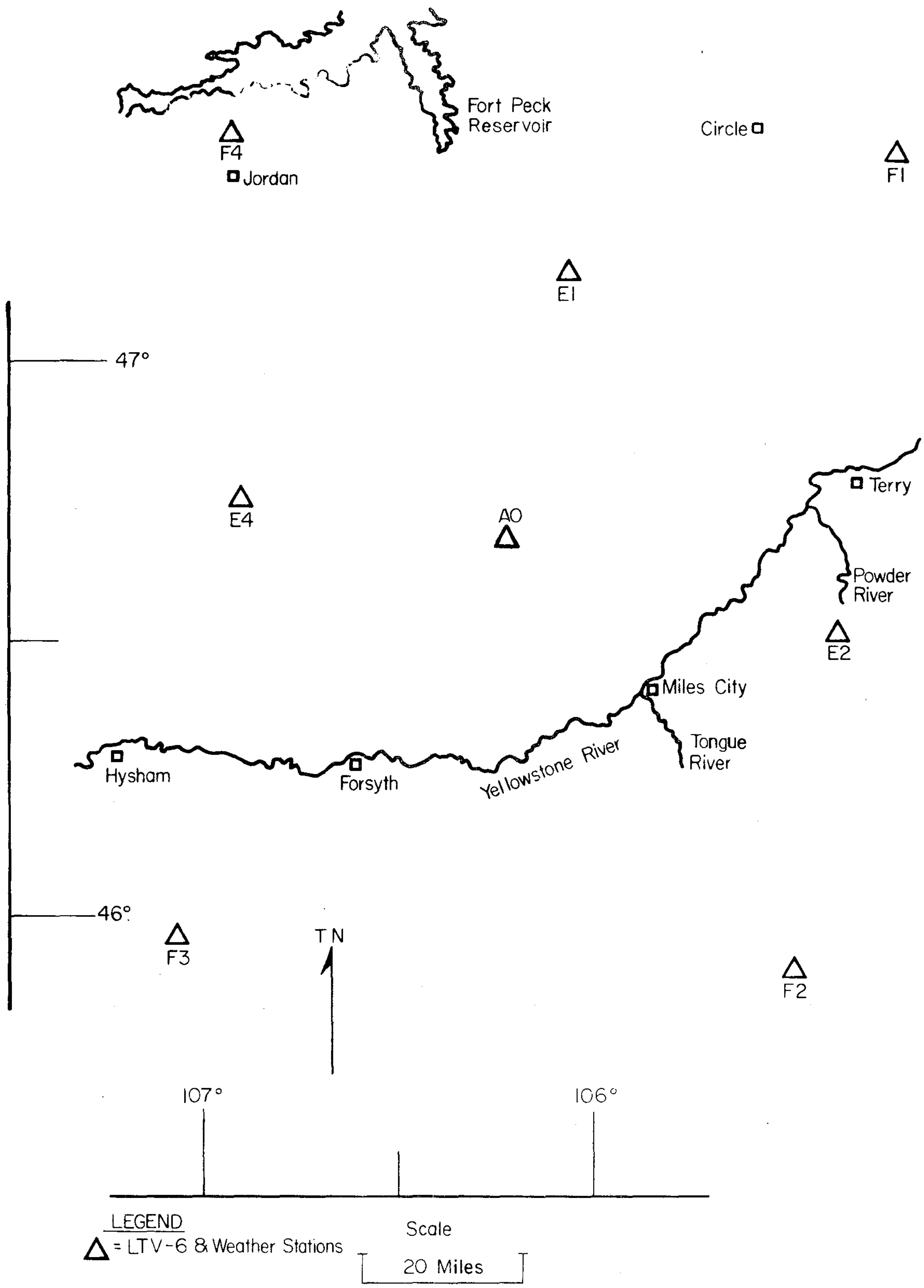


Figure 4.3 LAMA Geometry and Sensor Locations

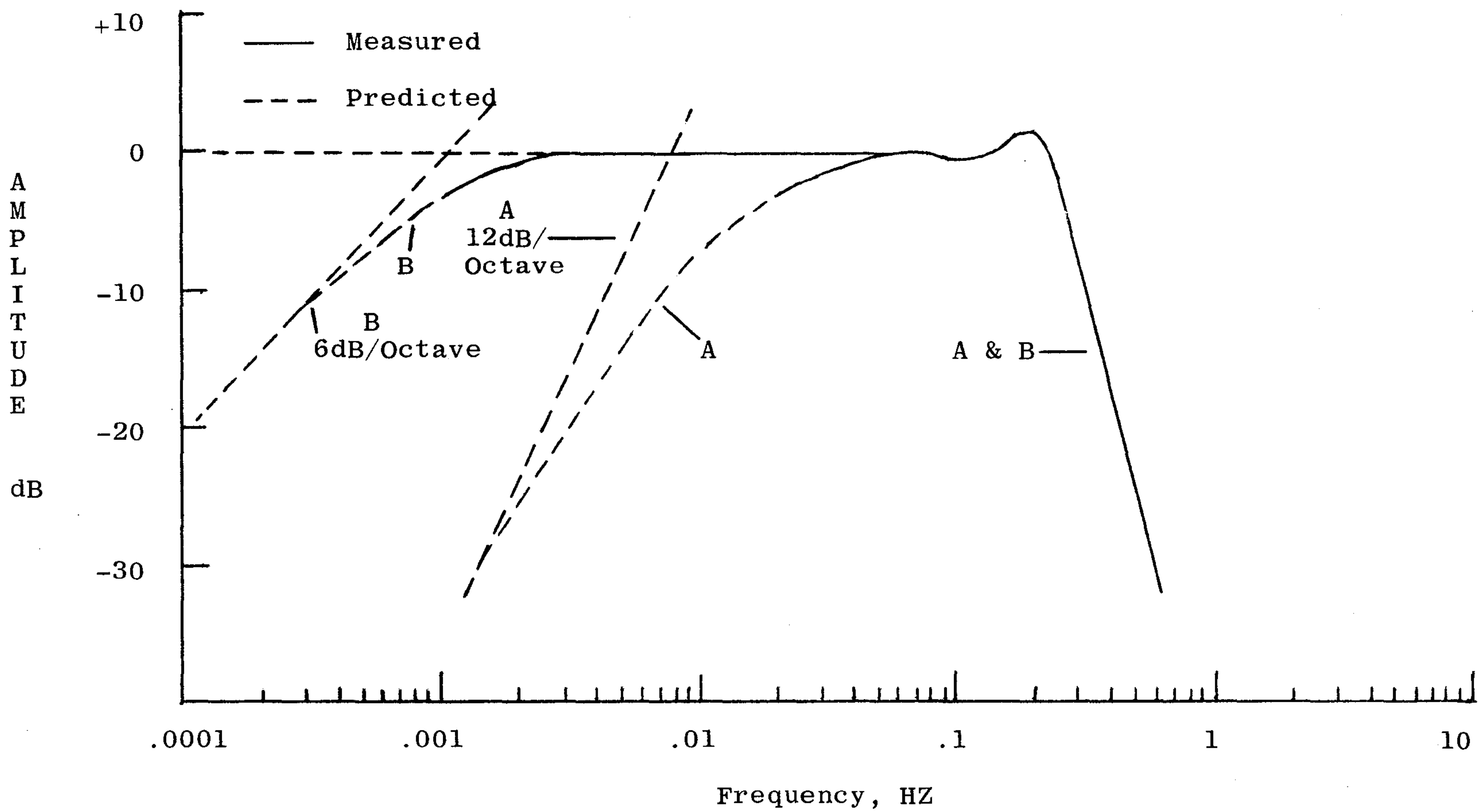


Figure 4.4 Microbarograph Frequency Response A and B.

TABLE XV

PERFORMANCE CHARACTERISTICS OF THE SP CALIBRATION OSCILLATOR

OVERALL FOR THE ARRAY	INDIVIDUAL FOR A SUBARRAY
Amplitude: (15-week test)	Amplitude: (15-week test)
Mean 409.46 nm p-p (20.68 Vpp)	Nominal 396 nm p-p (20.00 Vp-p)
Stability ± 4.7%	Stability:
	best (C1: max dev, .3%)
	402.76 nm p-p $^{+0.11\%}_{-0.19\%}$
	worst (D4: max dev 7.5%)
	395.76 nm p-p $^{+3.19\%}_{-4.29\%}$
Frequency: (32-day test)	Frequency: (32-day test)
Mean 0.99876 sec	Nominal 1.000 sec/cycle
Stability $^{+0.66\%}_{-0.40\%}$	Stability:
	best (D1, σ=1.10x10^{-4})
	1.000407 sec/cycle $^{+0.026\%}_{-0.025\%}$
	worst (C4, σ=3.72x10^{-4})
	.999305 sec/cycle $^{+0.16\%}_{-0.03\%}$

TABLE XVI

SP CALIBRATION OSCILLATORS OUTPUT FREQUENCY TEST RESULTS

SUBARRAY	MEAN PERIOD in seconds	STAND. DEV. in seconds x 10^{-4}	MAXIMUM PERIOD in seconds	MINIMUM PERIOD in seconds	MAXIMUM DEVIATION in seconds x 10^{-4}
AO	1.003775	2.0129	1.004206	1.003332	8.74
B1	0.997774	1.9727	0.998168	0.997356	8.12
B2	0.996184	2.3494	0.996950	0.995764	11.86
B3	1.000453	2.1084	1.001124	1.000220	9.04
B4	1.000207	3.0062	1.000645	0.998660	19.85
C1	0.995803	1.9550	0.996498	0.995524	9.74
C2	1.005310	2.4931	1.006010	1.004937	10.73
C3	0.998575	2.0460	0.999000	0.998146	8.54
C4	0.999305	3.7217	1.000902	0.998969	19.33
D1	1.000407	1.1023	1.000668	1.000156	5.12
D2	0.996283	2.7554	0.996850	0.995519	13.31
D3	1.002922	2.8240	1.003253	1.001835	11.42
D4	0.996044	2.2426	0.996362	0.995824	5.38
E1	0.999733	2.7140	1.000000	0.998334	16.66
E2	0.994772	1.4551	0.994927	0.994129	7.98
E3	0.998579	2.5889	0.999642	0.998223	14.19
E4	1.000998	1.7346	1.001359	1.000573	7.86
F1	0.999236	1.4048	0.999523	0.999007	5.16
F2	0.996481	1.9894	0.996805	0.996082	7.23
F3	0.997412	2.2873	0.998106	0.997075	10.31
F4	0.995504	2.3672	0.996541	0.995182	13.59
MAXIMUM	1.005310	3.7217	1.006010	1.004937	19.85
MINIMUM	0.994772	1.1023	0.994927	0.994129	5.12

channel sensitivity and, subsequently, channel stability. However, an error in sensitivity is introduced since the oscillator periods do differ slightly from 1.0 second. The worst case is that of subarray E2 where the difference between 1 second and the mean period is 5.228 milliseconds. At this subarray, if a channel output is such that the sensitivity is 20 mV/nm at the oscillator period of 0.994772 second and the TESP program output assumes the period to be exactly 1.0 second, the reported sensitivity will be 19.794 mV/nm, an error of 0.206 mV/nm. Since this is the worst case noted in the array, the error in SP channel sensitivity due to variation in oscillator period could be expected to be within 1%.

4.3 Failure Report

The array system and equipment failures which occurred this quarter are discussed in this section. All the failures are classified according to the type of failure and include these five classifications:

(1) System failure - A failure resulting in zero or no system output which prevents the system or equipment assembly from performing its primary function and identified as a Type 1 failure.

(2) Mode failure - A failure resulting in a zero or no system output only during one of several different modes of operation; a Type 2 failure.

(3) Limited failure - A failure resulting in a system output which is outside the allowable tolerance limits but permits degraded performance; a Type 3 failure.

(4) Latent failure - A failure which changes a system output either by an amount less than the allowable tolerance or from the nominal output when no tolerance limits have been established; a Type 4 failure.

(5) Temporary failure - A failure produced by an operating or environmental stress which results in no permanent physical damage; a Type 5 failure.

Table XVII indicates the number of failures detected and corrected in each of the twelve array systems. In decreasing order the three systems with the largest number of failures were: the PDP-7 computer, LDC Test and Support, and the SP sensor. During this quarter operation of the ESYS microbarograph system was discontinued, therefore, in subsequent reports the ESYS microbarograph system will be eliminated from this failure report.

TABLE XVII

LASA SYSTEM FAILURE DETECTIONS AND CORRECTIONS

DECEMBER 1971 - FEBRUARY 1972

	STARTING BACKLOG	DETECTED	CORRECTED	ENDING BACKLOG
SP SENSOR	15	14	12	17
LP SENSOR	0	2	1	1
LTV-6 MICROBAROGRAPH	0	3	0	3
ESYS MICROBAROGRAPH	0	0	0	0
METEOROLOGICAL SYSTEM	0	0	0	0
SEM	0	5	4	1
POWER SYSTEM	0	4	4	0
360 COMPUTER	0	7	7	0
PDP-7 COMPUTER	6	34	33	7
LDC DIGITAL	0	1	0	1
LDC ANALOG	1	8	9	0
LDC TEST AND SUPPORT	0	21	21	0
TOTALS	22	99	91	30

The distribution of the equipment failures within each system is shown in Table XVIII.

The tape units in the PDP-7 system accounted for 26 of the 33 failures in that system. These units are in constant use and mechanical wear accounts for the failures. Another expected failure rate is the battery replacements in the MDC units in the LDC Test and Support System. Of the 12 failures in the Short-Period System, all were RA-5 amplifiers and only 2 failed completely; the others were either intermittant problems or out-of-tolerance outputs.

Description of other equipment repairs can be found in Section VI.

4.4 Array Aging Study

A review of the aging effects has been initiated to determine which systems and equipment are reaching or have reached the point in their operating life when the effects begin to occur at an increasing rate. The attempt is being made to identify both the current and some potential failure modes.

The approach to be used during this study (also the one hoped to be most successful considering the capabilities available at the LASA facilities) draws upon the experience of the personnel to first select those equipment failures which they have direct experience with and know to be related to equipment aging. Once an equipment aging failure is selected, a review of information from WOSR and the work order file is made to show how extensive the particular failure mode is operating in the array. This information is used to estimate the impact of the failure mode on the future operation of the array.

At the present time aging effects have been identified in the following equipment: PDP-7 computer tape decks, MDC chart recorders, Develocorders, CTH vault walls and doors, WHV barrels, RA-5 amplifier bias batteries, and miscellaneous data center equipment, such as, air conditioners, air compressors, blowers and cabinet blower motors. As expected, the majority of aging conditions in these equipment are mechanical in nature. The study analysis will indicate in detail the impact of the conditions, e.g., are they repairable and restorable or do they require replacement.

TABLE XVIII

EQUIPMENT FAILURES

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					TOTAL
	1	2	3	4	5	
Short-Period System						
Seismometer	0	0	0	0	0	0
WHV Panel W/RA-5	2	0	5	3	2	12
RA-5 Power Supply	0	0	0	0	0	0
WHV Junction Box	0	0	0	0	0	0
WHV/Cables	0	0	0	0	0	0
CTH Junction Box (SP)	0	0	0	0	0	0
Total	2	0	5	3	2	12
Long-Period System						
Vertical Seismometer/Tank	0	0	0	0	0	0
Horizontal Seismometer/Tank	0	0	0	0	0	0
LP Vault/Cabling	0	0	0	0	0	0
LP Junction Assembly	0	0	0	0	0	0
Motor Assembly	0	0	0	0	0	0
Seismic Amplifier, Type 2	0	0	1	0	0	1
Amplifier Power Supply	0	0	0	0	0	0
CTH Junction Box (LP)	0	0	0	0	0	0
Total	0	0	1	0	0	1
LTV-6 Microbarograph						
Microbarograph	0	0	0	0	0	0
Power Supply	0	0	0	0	0	0
Cabinet/Cabling	0	0	0	0	0	0
Pipe Array	0	0	0	0	0	0
Total						
ESYS Microbarograph						
Acoustical Can/Cabling	0	0	0	0	0	0
Capsule	0	0	0	0	0	0
Oscillator	0	0	0	0	0	0
Discriminator/Power Supply/Cables	0	0	0	0	0	0
Pipe Array	0	0	0	0	0	0
Total	0	0	0	0	0	0

TABLE XVIII

EQUIPMENT FAILURES (CONTINUED)

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					TOTAL
	1	2	3	4	5	
Meteorological System						
Aerovane, Wind Direction	0	0	0	0	0	0
Aerovane, Wind Speed	0	0	0	0	0	0
Pole Assembly	0	0	0	0	0	0
Pole Junction Box/Cabling	0	0	0	0	0	0
Temperature Probe	0	0	0	0	0	0
Electrobarometer/Baffle	0	0	0	0	0	0
Rain Gauge	0	0	0	0	0	0
Rain Gauge Electronics Panel	0	0	0	0	0	0
Total	0	0	0	0	0	0
Subarray Electronics Modules						
Input Drawer #1	0	0	0	0	0	0
Input Drawer #2	2	0	0	0	0	2
Multiplexer/ADC	0	0	0	0	0	0
Output Drawer	0	0	0	0	0	0
PDC Drawer	0	0	1	0	0	1
ACC Cabinet	1	0	0	0	0	1
SEM Cabinet/Cabling	0	0	0	0	0	0
Alarms	0	0	0	0	0	0
Total	3	0	1	0	0	4
Power System						
Control Drawer	0	0	1	0	0	1
Inverter	2	0	0	1	0	3
Charger	0	0	0	0	0	0
Battery	0	0	0	0	0	0
SOLA Transformer	0	0	0	0	0	0
Rack/Cabling	0	0	0	0	0	0
Isolation Transformer	0	0	0	0	0	0
Breaker Panel	0	0	0	0	0	0
Vault/Wiring/Breakers/Outlets	0	0	0	0	0	0
Total	2	0	1	1	0	4

TABLE XVIII

EQUIPMENT FAILURES (CONTINUED)

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					TOTAL
	1	2	3	4	5	
360 System						
CPU 2044	1	0	0	0	0	1
Disc Drive 2315	0	0	0	0	0	0
Typewriter 1052	5	0	0	0	1	6
Card Reader 2501	0	0	0	0	0	0
Data Control 1826	0	0	0	0	0	0
Data Adapter 1827	0	0	0	0	0	0
Data Adapter 2701	0	0	0	0	0	0
Total	6	0	0	0	1	7
PDP-7 System						
Computer	1	0	0	0	3	4
Teletypewriter KSR-35	0	0	0	0	0	0
Card Reader	0	0	2	0	0	2
SOU	0	0	0	0	0	0
Interface	0	0	0	0	0	0
Tape Unit #19	2	0	2	0	0	4
Tape Unit #32	7	0	3	0	0	10
Tape Unit #33	8	0	4	0	0	12
Incremental Recorder	0	0	0	0	1	1
Total	18	0	11	0	4	33
Digital System						
Timing System #1	0	0	0	0	0	0
Timing System #2	0	0	0	0	0	0
Digital Data Simulator	0	0	0	0	0	0
Power System	0	0	0	0	0	0
PLINS	0	0	0	0	0	0
MINS	0	0	0	0	0	0
Total	0	0	0	0	0	0

TABLE XVIII

EQUIPMENT FAILURES (CONCLUDED)

ARRAY SYSTEM/EQUIPMENT	NUMBER OF FAILURES					
	TYPE OF FAILURE					TOTAL
	1	2	3	4	5	
Analog System						
D/A Patch Panel Cabinet	0	0	0	0	0	0
D/A Converter #1	0	0	0	0	0	0
D/A Converter #2	0	0	0	0	0	0
D/A Converter #3	0	0	0	0	0	0
D/A Converter #4	0	0	0	0	0	0
FM System	0	0	0	0	0	0
16 Channel Chart Recorder	0	0	0	0	0	0
WHV Receiver	0	0	0	0	0	0
Analog Calibration System	0	0	0	0	0	0
Analog Timing System	0	0	1	0	0	1
SP Develocorder	1	0	2	0	1	4
LP Develocorder	0	0	4	0	0	4
Total	1	0	7	0	1	9
LDC Test and Support System						
MDC-1	0	0	7	1	2	10
MDC-2	0	0	7	0	0	7
Clocks	0	0	0	0	0	0
Film Viewer	1	0	0	0	0	1
Film Duplicator	0	0	0	0	0	0
Copier	0	0	1	0	0	1
Emergency Lights	0	0	0	0	0	0
Compressor, Blower	0	0	0	0	0	0
Digital Clocks	0	0	0	0	0	0
Air Conditioners	0	0	1	0	0	1
Humidifier	0	0	0	0	0	0
Tape Cleaner	0	0	1	0	0	1
Electrostatic Filters	0	0	0	0	0	0
Total	1	0	17	1	2	21

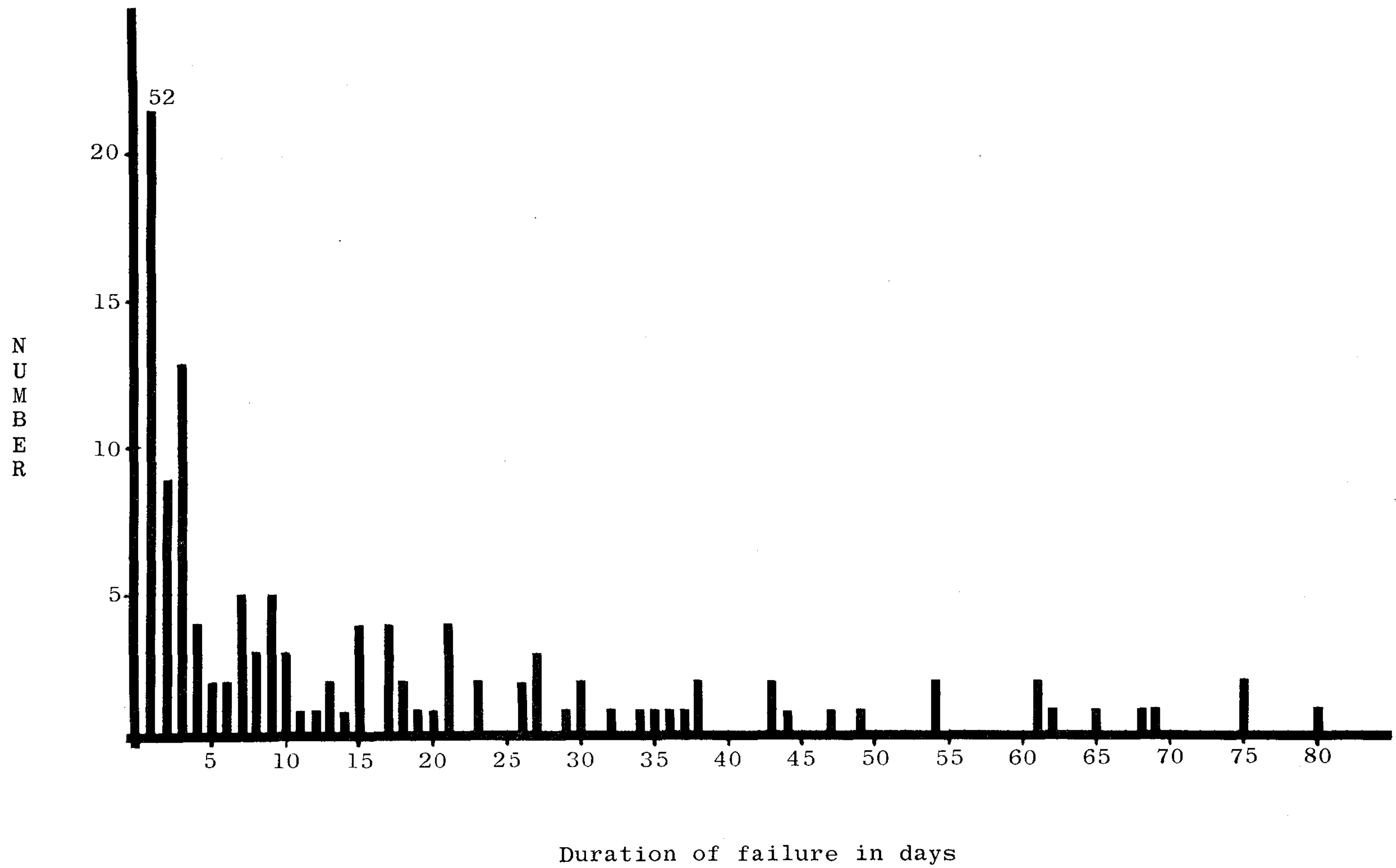


Figure 4.5 Distribution of the Number and Duration of the Defective SP Seismographs between 5 Sept. 71 and 29 Feb. 72

SECTION V

IMPROVEMENTS AND MODIFICATIONS

5.1 General

Important to the operation of the Montana LASA is the continuing incorporation of improvements and modifications into the various equipment. These improvements permit increased efficiency in the utilization, operation and maintenance of the seismic observatory's systems. The improvements are categorized into these three areas, PDP-7 programming, array equipment and data center equipment. Improvements in the PDP-7 programming result in more efficient operation and increase the data collection capability of the array performance measurement activity. Modifications to the array and data center equipment are made to reduce the need for maintenance (i.e. improve reliability), to improve data quality, or to extend the operating capability.

5.2 PDP-7 Programming

Two programming efforts are reported for this period. One, a new patch program, overlays a portion of the PDP-7 memory during MOPS operation to determine some SP seismograph channel parameters at subarrays B1 and F3. The other, a program modification, improves the ability of program TESP to determine sensor channel offset.

5.2.1 TASP

To assist in the analysis of the data collected from the TESP program, a new program for measurement of the RA-5 amplifier was requested. Program TESP (Ref. 4) provides measurements from the SP channel output resulting from a nominal 400 nm p-p sinusoidal input. Since variations in the output originate from particular equipment in the channel, program TASP was prepared to measure and isolate these channel variations. The availability of the seismometer-calibration bypass relay on the WHV's only at subarrays B1 and F3 limit the use of this program to these two subarrays.

TASP permits the PDP-7 computer to control the sending of telemetry commands TC-06, TC-15, and TC-08 to a selected subarray, either B1 or F3. The peak-to-peak sinusoidal responses (A_{ch}) from each of these commands is determined from

$$A_{ch} = 2.136 \times 10^{-2} \sum_{i=1}^{40} (X_i) \text{ mV} \qquad (5\text{-}1)$$

The RA-5 amplifier gain (G_i) at 1.0 second for each channel is then calculated from

$$G_i = 1.25 \times 10^4 \frac{(A_{ch})_{TC15}}{(A_{ch})_{TC08}} \tag{5-2}$$

and the SEM amplifier gain (G_2) from

$$G_2 = \frac{10^2 \ (A_{ch})_{TC08}}{(A_{30})_{TC08}} \tag{5-3}$$

Further, the seismometer voltage output, (E) is determined from

$$E = 8 \times 10^2 \frac{(A_{ch})_{TC06}}{(A_{ch})_{TC15}} \quad \mu V \tag{5-4}$$

The format of the program output is shown in Figure 5.1.

5.3 Array Equipment

Two modifications to the array equipment are in the preparation stage. These are (1) the SP channel CTH gain control and (2) the ESYS microbarograph equipment removal.

5.3.1 SP Channel CTH Gain Control

A VSC approved modification to provide a short-period sensor channel gain adjustment in the CTH is being prepared for installation. This modification, designated P-82, will allow periodic adjustment of all sensor channels thereby reducing somewhat the variations in the array mean sensitivity caused by seasonal temperature changes. At the present time channel gain is adjusted at each individual WHV. During the winter months travel to most of the WHV locations is impossible while most of the CTH locations are accessible. With this modification one crew, during a single visit to the CTH can adjust all of the subarray's sensor channels. This modification will not replace visits to the WHV necessary to repair unstable or improperly adjusted amplifiers or to replace defective seismometers but will make possible maintaining the array closer to the nominal sensitivity throughout the year.

In the development of this modification keeping the overall SP channel characteristics from changing was considered of upmost importance. Verification that the seismic channel dynamic range and the channel sensitivity were unchanged by the new design was accomplished. Some experience with centrally-located SP channel gain adjustments had previously been obtained from the subarray E3

```
B1

2002:41.7 - 2003:11.7

TC-06 IN MV

    53     -      -    9116   8204    -    9373   8207   8071    -
    -    7690   8917    -     8167   8211  4720    -      -     7806
  8360    32    9074   8409   8760    -     -      -      -    10210

2003:11.7 - 2003:41.7

TC-15 IN MV

    51     -      -    5949   9363    -    6902   6705   5507    -
    -    6282   7439    -     5838   7316  4652    -      -     5336
  8245    33    6553   7067   8035    -     -      -      -    10207

2003:41.7 - 2004:11.7

TC-08 IN MV

 12040     -      -   12131  11984    -   12187  12212  12005    -
    -   11990  12153    -    12110  12075 12077    -      -    11842
 12071  12096  12110  12072  12109    -     -      -      -    10213

RA-5 GAIN
    52     -      -    6129   9766    -    7079   6863   5734    -
    -    6549   7651    -     6026   7573  4814    -      -     5632
  8538    34    6764   7317   8294    -     -      -      -      -

SEM GAIN X 100
   117     -      -     118    117    -     119    119    117    -
    -     117    118    -      118    118   118    -      -      115
   118    118    118    118    118    -     -      -      -      100

SEIS OUT IN UV
   831     -      -    1225    700    -    1086    979   1172    -
    -     979    958    -     1119    897   811    -      -     1170
   811     -    1107    951    872    -     -      -      -      -
```

Figure 5.1 Program TASP Printout

configuration. The design at E3 has not been completely satisfactory because the adjustment varies the amplifier termination as well as channel gain. The comparison between the present circuit and the modified circuit design and setup presented in the two paragraphs which follow indicate that the overall channel characteristics are unchanged by this modification.

The original SP channel circuit is shown in Figure 5.2. The amplifier is set for a gain of 7K and a damping card selected for proper damping (15:1-22:1). The 50K-ohm dual potentiometer is adjusted to provide an output of 6.67 volts peak-to-peak out of the amplifier terminated in 10K ohms; with the 20V p-p, 1 Hz, calibration signal applied to the calibration coil of the seismometer. The jumpers can be removed from the switch card and another damping resistance selected if more attenuation of the seismometer output is required but is very rarely needed. The 10K ohm termination is provided in the SEM Input Protect Card. The Balanced-Unbalanced Amplifier and Filter card converts the balanced signal to an unbalanced signal referenced to ground, provides a nominal gain of 1.2 for a final calibrated output of 8V p-p, and attenuates all frequencies above 5 hZ to prevent aliasing in data processing. Also, in converting the balanced signal high common-mode rejection of line noise is provided.

Figure 5.3 shows a modified SP signal channel circuit. Note that the well head vault (WHV) circuitry remains the same. The 10K-ohm amplifier termination is now provided on the CTH protect card installed in the CTH junction box. The gain of the balanced-unbalanced amplifier and filter card has been changed from 1.2 to 2.0. The amplifier is still set for a gain of 7K and the 50K-ohm, dual potentiometer in the WHV is set for an amplifier output of 6.67V p-p as measured across the 10K-ohm termination. The 5K-ohm, dual trimpot in the CTH protect card is then adjusted to provide a channel calibration output of 8V p-p. The WHV adjustments remain the same, the termination is constant, and the only change is in the SEM amplifier circuit.

Tests were conducted to insure no adverse effects on the stability, dc balance and common-mode rejection of the modified balanced-unbalanced amplifier. The effects on these channel qualities due to the 0.8 increase in gain were not measurable. The 5K-ohm dual trimpot has a tracking capability between the two sections of 5%. In testing the CTH protect card circuit it was found that the two sections had to be unbalanced by 50% to cause a 5 millivolt increase in common mode signal; a 5% unbalance was not measurable. The circuit, as shown in Figure 5.3 was installed in sensor channel 0571 at subarray D2 on 5 February 1971 and has operated satisfactorily to the present time.

Another consideration in developing this modification was the effect on the telemetry-controlled calibration of the sensor channels since computer programs have been developed to utilize certain of these telemetry commands. The analysis of array performance is based on the continued collection of such calibration

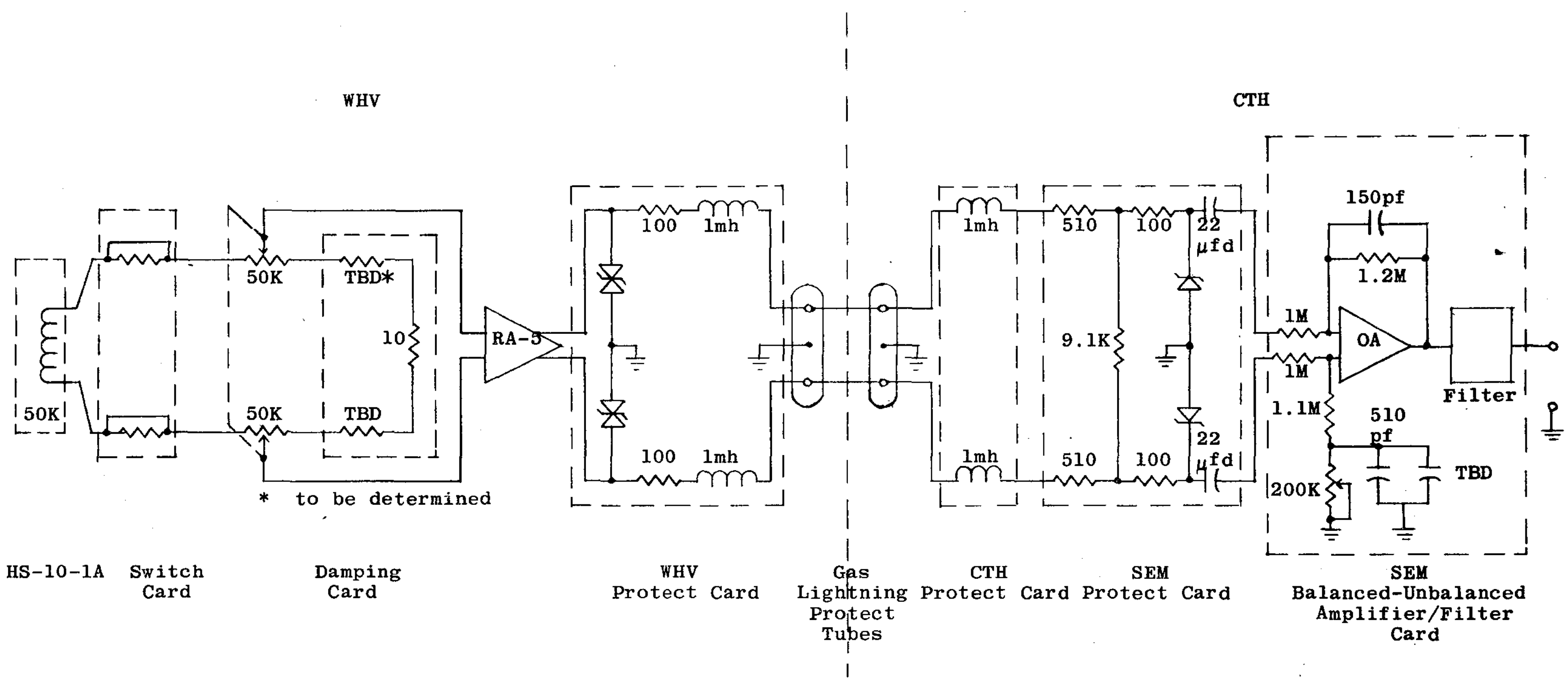


Figure 5.2 Present SP Seismograph Analog Signal Path

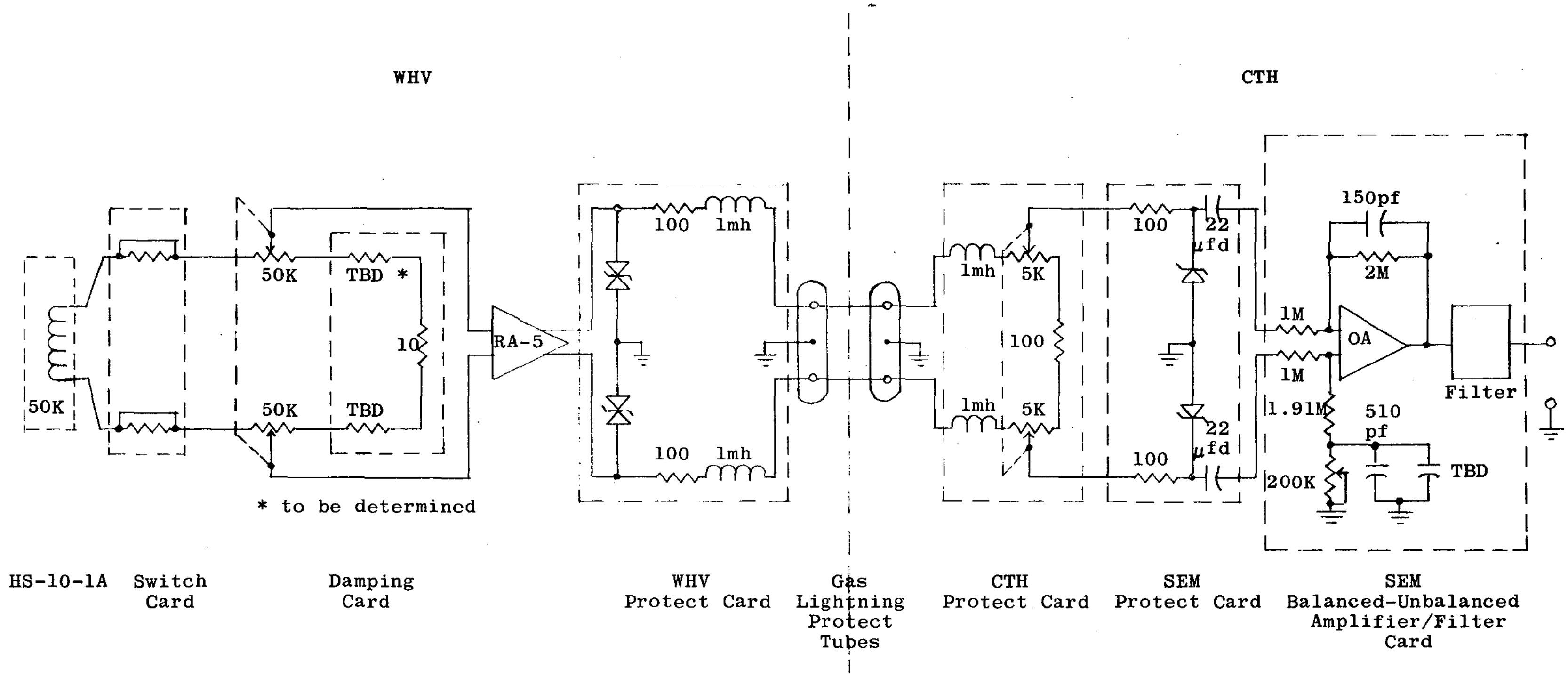


Figure 5.3 Modified SP Seismograph Analog Signal Path

data. A gain increase in the SEM input drawer would affect all telemetry commands that check the SEM portion of the channels. The original telemetry controlled calibration signal flow can be seen in Figure 5.4. In order not to invalidate any of the computer programs or the present scheme for collecting data, the SEM control and input drawers are to be modified as shown in Figure 5.5. With this modification both the 1 Hz and .04 Hz signal use the same full-scale reference amplifier to condition the signal on word 30. The other amplifier is modified to produce a gain of 0.25 and to supply the calibration signal to the SP input drawer channels. The SEM control drawer changes eliminate telemetry command TC-35, originally a spare, and TC-4 will produce a positive 6 Vdc output instead of a positive saturated (7 Vdc) output. The relay (K-12) originally operated by TC-35 now energizes with K4. The results of all other telemetry commands remain unchanged. The SEM at subarray D2 was modified 3 February 1972 and has operated without difficulty.

The modification will proceed on a site-to-site basis as parts are received. All spare SEM drawers and cards, and CTH protect cards will be modified in the shop and then installed in the subarray. The SP channels will then be adjusted, as previously stated, to operate at the same level as before the modification. The coming summer season provides an insufficient amount of time to visit each WHV in conjunction with the modification. All RA-5 amplifiers that have previously been replaced under the SP rehabilitation program have already been adjusted for a gain of 7K. As other WHV locations are visited under this continuing program the channels will be adjusted to this nominal setting. The modification, P-82, will initially be completed at subarray D2 and reviewed again before scheduling the remainder of the array.

5.3.2 ESYS Microbarograph Removal

The thirteen ESYS microbarographs are being removed from the array. The data from these sensors on subarray data word 18 have been disconnected from all subarrays except D3. The electronics equipment previously installed in the CTH has been removed and returned to the LMC to be prepared for shipment. In the spring when the frost is out of the ground, the microbarograph sensor reference volume cans will be removed. These cans are buried about 30 inches in the ground.

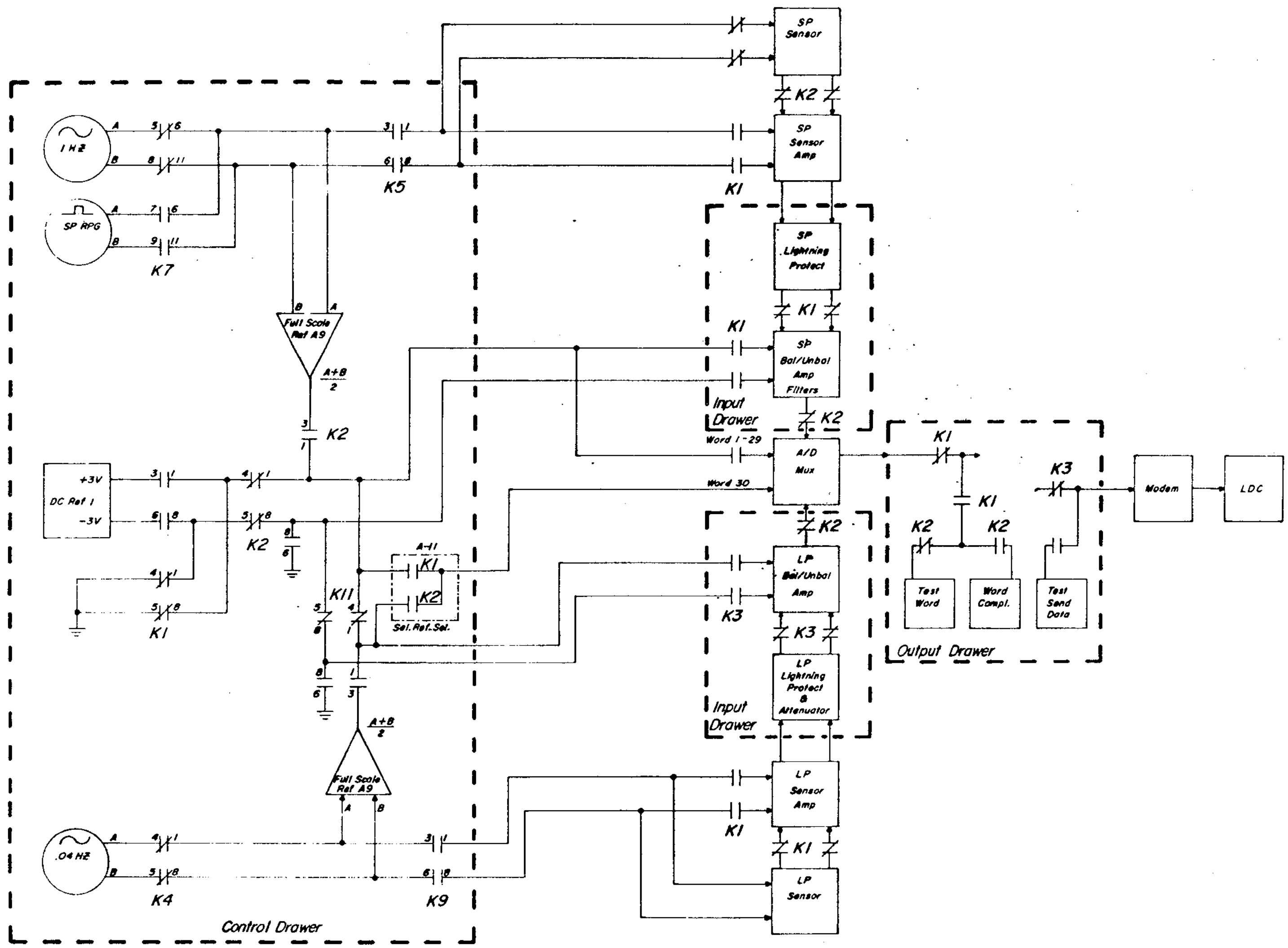


Figure 5.4 Present Calibration Signal Flow

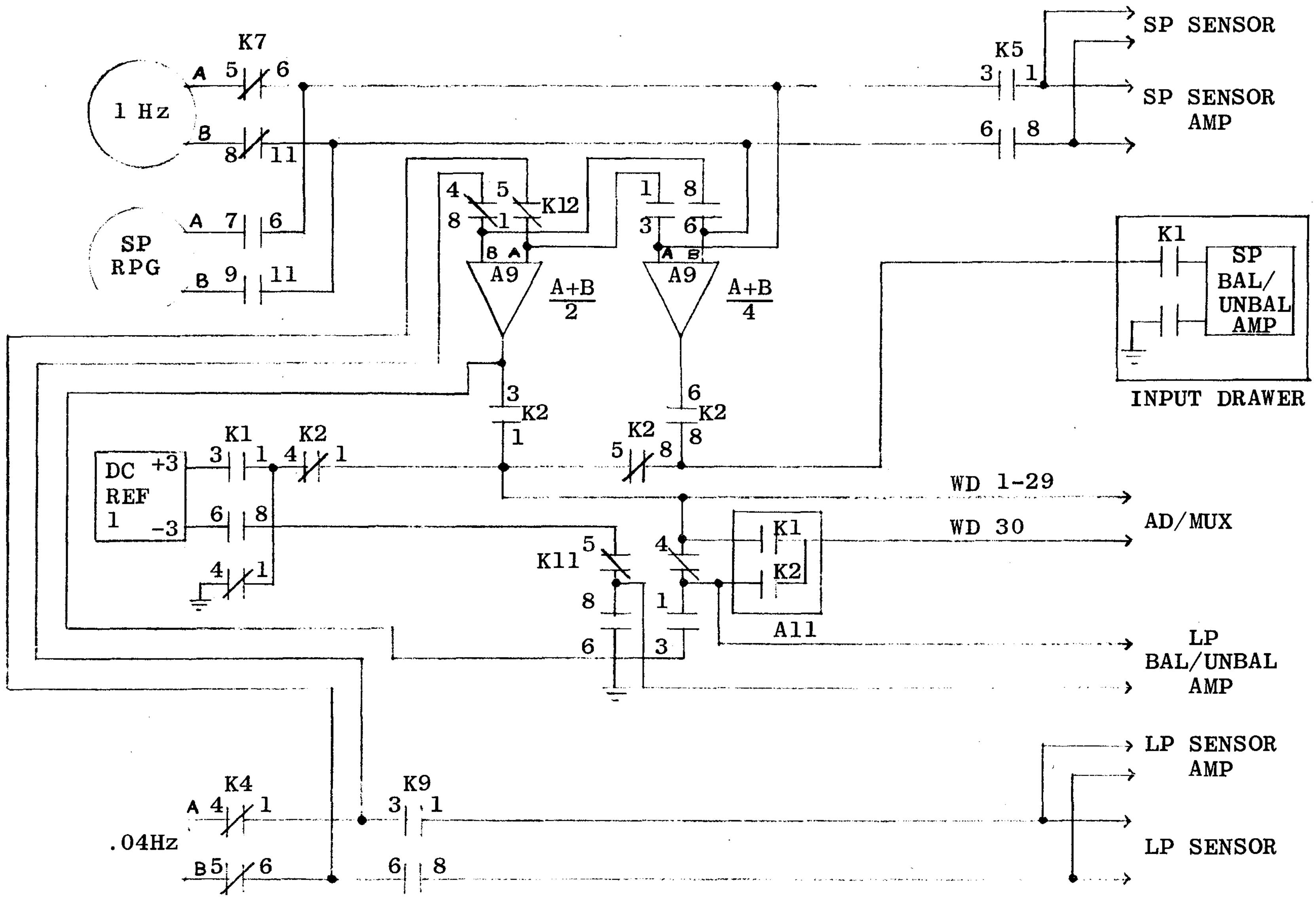


Figure 5.5 Modified Calibration Signal Flow

SECTION VI

MAINTENANCE

6.1 General

Maintenance activity at LASA includes correction of failures, preventive maintenance, modifications, special tests required for evaluations or quality control activities, facility and access maintenance and improvements, and vehicle maintenance. LASA maintenance activity is discussed in three different catagories: Data Center (LDC), Maintenance Center (LMC), and Facilities Support. The LDC in Billings covers these six systems: the IBM 360/44 computer, the DEC PDP-7 computer, LDC Digital, LDC Analog, and LDC Test and Support. The LMC located in Miles City maintains all array equipment systems which are comprised of SP Sensor, LP Sensor, LTV-6 Microbarograph, ESYS Microbarograph, Meteorological, SEM, and Power. Facilities Support provides maintenance of buildings, vehicles, land leases, and array facilities such as cable trenches, access trails, fences, WHV sites, and CTH sites.

Table XIX summarizes the number of all equipment (LASA) and facility (utility) work orders completed this quarter. The 298 completed work orders represented 346 separate maintenance actions by technical personnel. The number and type of operational equipment failures corrected are discussed in paragraph 4.4. Work orders are used to document all LASA maintenance activity. Although the actual time or complexity required of a task is not indicated, the summary does indicate the type of work performed and the size of the work load. During this quarter 89% of the scheduled preventive maintenance routines were completed. Such considerations as weather, work load, and man hours available affect the number of routines completed each month.

6.2 Data Center

The TD-570 tape units in the PDP-7 system continue to require maintenance due to mechanical breakdowns. The units are repairable and maintained to operate within factory specifications. The main problem, availability of replacement parts, is related to the age of the units (7 years). Since many of the parts are no longer stocked or manufactured, procurement requires the supplier to re-tool and manufacture the parts. This naturally increases their cost and delivery time.

To enable us to maintain the tape units in the future and bypass the problem of increased cost and outage time, five of the TD-570 units and compressors which were scrapped by MIT Lincoln Laboratory are now available at the LDC. Several parts from these units have already been used in the repair of our three

TABLE XIX

WORK ORDER SUMMARY

DECEMBER 1971 - FEBRUARY 1972

WORK ORDER TYPE	BACK LOG START OF QTR	INITIATED	COMPLETED	BACK LOG END OF QTR
System - A	27	159	135	51
Subassembly - B	40	13	20	33
Component - C	127	6	117	16
Total	194	178	272	100
Utility:				
Cable trench & trail inspection	0	2	2	0
Cable trench backfill	1	0	0	1
WHV sites landscaped	0	0	0	0
Marker posts &/or WHV covers replaced	0	0	0	0
CTH maintenance	7	9	11	5
Vehicle maintenance and inspection	3	9	11	1
Fence inspections	4	1	2	3
Trail repairs	2	0	0	2
Total	17	21	26	12
WORK ORDER TOTALS	211	199	298	112

on-line units. When all usable parts have been exchanged, the salvaged units will be turned in for scrap.

One failure in the IBM 360 CPU bears mention. An intermittant bit in a storage register required replacement of the logic card installed in location A-A3J4. This is the same logic card that was replaced on May 2, 1971 in conjunction with another failure. The 90-day warranty had expired and since IBM neither makes available individual card components nor performs card repairs, purchase of a new logic card was necessary. Other failures in the IBM computer system resulted from broken rotate tapes and a defective carriage return cord in the 1052 typewriter. Wear on these parts is expected since the typewriter operates regularly 24-hours a day.

6.3 Maintenance Center

Weather and road conditions greatly limited field repairs during this quarter. All subarrays were visited during the quarter but many of the visits required use of the snow tractor. Travel to individual WHV locations was not advisable. There were, however, 63 field trips covering 9,706 miles and one trip to the PMEL at Great Falls to pick up calibrated test equipment.

The major efforts at LMC during this quarter were the completion of outstanding B and C type work orders. These included the repair of SEM cards, RA-5 amplifiers, and HS-10-1/A seismometers. All development work on modification P-82, SP Channel CTH Gain Control, was completed and the circuits tested both in the shop and the field.

The SP rehabilitation program is planned to start in April. Sixteen subarrays will be scheduled this season. Table XX will be used as a guide for scheduling amplifier and seismometer repairs. This season all repair requirements will be based on the new tolerances established 1 September 1971. Along with the preventive maintenance schedule and installation of P-82 a full work load for LMC is anticipated.

6.4 Facilities Support

Poor weather and road conditions prevented any land restoration, cable trench and trail repairs, or CTH repairs during this quarter. All subarray CTH areas were inspected during the quarter and minor repairs to such items as door seals were made to prevent equipment damage.

A total of 22 landowners were contacted regarding LASA operations and lease agreements.

Oil exploration drilling occurred at one location 11 miles from WHV 83 at subarray F1. The well was drilled to a depth of 10,700 feet. The location was Dawson County, SESE Section 33, 18 North and 53 East.

TABLE XX

SP CHANNEL STATUS, 29 FEB. 72

SUBARRAY	CALIBRATION RESPONSE		NATURAL FREQUENCY		SENSITIVITY RESPONSE		SEISMIC EVENT POLARITY		SEISMIC EVENT AMPLITUDE	
	SAT.	UNSAT.	SAT.	UNSAT.	SAT.	UNSAT.	SAT.	UNSAT.	SAT.	UNSAT.
AO	13	4	9	7	13	3	17	0	17	0
B1	11	6	11	5	15	1	17	0	17	0
B2	12	5	12	4	14	2	17	0	17	0
B3	12	5	14	2	7	9	17	0	17	0
B4	15	2	11	5	10	6	17	0	17	0
C1	11	5	12	3	13	2	16	0	16	0
C2	11	6	12	4	12	4	17	0	17	0
C3	15	2	12	4	12	4	17	0	17	0
C4	8	9	14	2	13	3	17	0	17	0
D1	15	2	13	3	12	4	17	0	17	0
D2	21	0	19	1	19	1	21	0	21	0
D3	13	4	14	2	12	4	17	0	17	0
D4	17	0	16	0	11	5	17	0	17	0
E1	16	1	12	4	15	1	17	0	17	0
E2	12	5	14	2	13	3	17	0	17	0
E3	24	1	25	0	23	2	25	0	25	0
E4	10	7	13	3	14	2	17	0	17	0
F1	12	5	15	1	14	2	17	0	17	0
F2	10	6	11	4	9	6	16	0	16	0
F3	13	4	13	3	14	2	17	0	17	0
F4	16	1	11	5	11	5	17	0	17	0
TOTAL	287	80	283	64	276	71	367	0	367	0

Erratic power-meter readings at subarray F2 last fall had resulted in excessive electric billing from this subarray. Frequent and careful reading of the power consumption by the maintenance crews prompted the power company to install a new watt-hour meter in December and to arrange for a credit to the billing. Normal readings have been obtained since the new meter was installed.

The rotary ventilator caps at all subarray CTH vaults have been replaced by a stationary cap with the same cubic feet/minute rating. Ventilation sufficient to dispel any explosive gas generated by the batteries is a necessary vault requirement. The rotary-type cap had a lifetime of about one year before the nylon bearings wore out. The stationary caps should be a permanent replacement.

SECTION VII

ASSISTANCE PROVIDED TO OTHER AGENCIES

7.1 Seismic Data Laboratory

Develocorder film recordings of selected SP sensor data are made for SDL. Each film covers a period of approximately twenty-four hours; film change is made at about 2200 GMT. Ninety-one films with the format described in reference 5 were recorded and shipped during this period.

Additionally, microbarograph array and related digital data are recorded by the PDP-7 computer's incremental recorder for shipment to SDL. Eighty VLR tapes were recorded and shipped.

7.2 Tonto Forest Seismological Observatory

A description of the LDC Develocorder gravity flow regulated chemical distribution system was provided to TFSO. Methods employed and materials used at the LDC to insure continued operation were indicated in conjunction with the system description.

7.3 MIT Lincoln Laboratory

Two tests were performed for the Seismic Discrimination Group to provide digital data recordings of the pseudo-random sequence responses from the SP seismometers at B1 and the pulse input responses from the LTV-6 microbarograph at F3 and F4. These tests used the telemetry controls available between the subarrays and the data center and the high-rate digital recording capability of the PDP-7.

SECTION VIII

DOCUMENTATION PROVIDED UNDER VT 2708

8.1 Technical Reports

The following reports were distributed as required by project VT 2708:

a. "Operation and Maintenance of LASA, Monthly Progress Report", Report No. 2056-71-14, December 1971.

b. "Operation and Maintenance of LASA, Monthly Progress Report", Report No. 2056-72-15, January 1972.

8.2 Operations Data

Thirteen weekly issues of the Defective Signal Channel Status and Data Interruption Log Reports and Develocorder operations logs were distributed to approved using agencies. A new issue of the Array Status Report (AS-65) was distributed.

8.3 Alternate Management Summary Reports

Three Alternate Management Summary Reports (AMSR) were prepared; one for each of the months December, January, and February.

REFERENCES

1. Philco-Ford Corp. Montana LASA Second Quarterly Technical Report AD846155, Billings, Mont., Nov. 68, Appendix A.

2. Philco-Ford Corp. Montana LASA Second Quarterly Technical Report AD885649, Billings, Mont., 15 June 71, p. 47.

3. Hoel, Port, and Stone Introduction to Probability Theory Houghton Mifflin Co., Boston, 1971, p. 186.

4. Philco-Ford Corp. Montana LASA Final Technical Report, Project VT 1708 T/R 2039-71-13, Billings, Mont., 22 Dec. 71, Appendix A-1.

5. ibid., p. 121.